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Salt Deposits in the Salina Group in Pennsylvania

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PREFACE

This report is the result of a study on the thickness and geographic extent of rock salt beds or layers located beneath the ground surface in central and western Pennsylvania. The salt layers were formed in an ancient sea that occupied the area over 400 million years ago during the geologic time period known as the Silurian Period. The salt layers are enclosed in a group of rock layers called the Salina Group.

The rock salt layers were studied to point out the tremendous quantity of rock salt present beneath the surface in Pennsylvania so that industries that utilize salt may locate areas that are economically favorable for the extraction of salt.

The information for this study was derived from the data recorded during the drilling of oil and gas wells that penetrated or passed through the rock salt layers. The various rock salt layers were identified by their individual characteristics and maps illustrating the thickness and extent of the salt layers were made. The basis for the division of the salt layers is from reports published concerning the same rock salt layers in the states of Michigan and Ohio.

Additional maps showing the relation between the rock salt and other rock layers above, below, and adjacent to the salt layers were made. These maps help show the relation between the deposition of the salt layers and neighboring rock layers in the same ancient sea. The relations allow speculation and the development of ideas concerning why and how the rock salt layers were formed.

This report should be of use to salt-utilizing industries, economic geologists, and all geologists and students interested in the formation and development of natural resources and geologic history.

The authors hope that this report will perform two functions. First, to stimulate industry to locate salt extracting and processing facilities in Pennsylvania; and secondly, to provide a basis for the further study of the geology of salt deposits.

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SALT DEPOSITS IN THE SALINA GROUP IN PENNSYLVANIA

By
William B. Fergusson
and
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ABSTRACT

Many areas in Pennsylvania contain salt beds of sufficient thickness and sodium chloride content to sustain a large salt-producing industry. The salt beds are usually found at considerable depth and although mining currently appears prohibitive, most of the salt could be successfully extracted by artificial brining techniques. In areas of Pennsylvania where thick salt reserves are near adequate water supply and transportation facilities salt extraction appears warranted.

The depth to the salt beds ranges from 2,200 feet in Erie County, to 8,200 feet in Fayette County, and 8,900 feet in Bradford County. The aggregate thickness of the salt ranges from 80 feet in Erie County, to 542 feet in Fayette County, and 776 feet in Bradford County.

The salt-containing Salina Group in Michigan was divided into informal stratigraphic units designated A through G by Landes (1945). These units were found equivalent to similar units in Ohio by Ulteig (1964). Correlation of the Salina Group to Ohio and Michigan shows that the salt beds in Pennsylvania are also contained within these distinct stratigraphic units. These units provide a definitive basis for the study of the distribution and origin of the Pennsylvania salt deposits.

Beds of salt occur within units B, D, E, and F. Unit B and D salt is found in northwestern and north-central Pennsylvania and Unit F salt deposits are located in northwestern, north-central, and southwestern Pennsylvania. The salt beds of unit E are thin and not extensive.

Units A, C, and G do not contain salt. Unit A is composed of interbedded gray to green shale and carbonate rocks and is considered to be equivalent to the upper light colored section of the Vernon Shale of the Salina Group in New York and with the lower part of the Wills Creek Formation in south-central Pennsylvania. The Bloomsburg Formation of Pennsylvania and the lower red section of the Vernon Shale of New York are considered equivalent and the red shale and siltstone beds observed beneath unit A in central Pennsylvania are restricted to the Bloomsburg Formation. Unit C is mostly shale and unit G is largely composed of calcareous dolomite.

The salt deposits were formed in specific areas because of the original sedimentary environment imposed by reef structures in the Lockport Dolomite and the deltaic complex of the Bloomsburg Formation.

INTRODUCTION

PURPOSE AND SCOPE

This study was undertaken to determine the distribution, thickness, and stratigraphic relations of the salt-bearing units contained in the Salina Group in Pennsylvania, which will provide basic geologic data to aid industry in the development of the salt deposits of Pennsylvania.

The Salina Group is a part of the Cayugan Series and the sequence of rocks in Pennsylvania is lithologically similar to the Cayugan Series of Michigan, Ohio, New York, and West Virginia. These rocks contain beds of salt within a consistent and repetitive lithologic sequence. The Cayugan Series consists of two rock units: the Salina Group and the overlying Bass Islands Group. This report is primarily concerned with the salt beds and associated lithologies within the Salina Group.

Michigan, Ohio, New York, and West Virginia are presently utilizing the extensive salt reserves of the Salina Group as a raw material source for the food and chemical industries.

METHOD OF INVESTIGATION

All the stratigraphic units considered in this report are located in the subsurface. The data used in compiling the report were obtained from oil and gas well records, sample descriptions, geophysical well logs, and the microscopic examination of well cuttings.

The primary data used in correlation from well to well is the similarity in gamma ray-neutron curves of the geophysical logs. Where good well samples were available, the gamma ray correlations were checked by microscopic examination.

The data were used to construct isopach maps of the salt and the salt-bearing units, structure contour maps, lithofacies sketch maps, and stratigraphic cross sections. The maps illustrate the subsurface stratigraphic relations and the geometric configuration of the lithologic units within the Salina Group and the associated salt beds.

Correlation of the units is based on lithologic and geophysical similarities to similar units in the Michigan Basin and northeastern Ohio.

REGIONAL GEOLOGY

The depositional environment of the Salina Group (Fig. 1) was partly the product of the growth and development of the Middle Silurian reefs in the Lockport Formation of the Niagaran Series and the distal portion of the Bloomsburg delta (Alling and Briggs, 1961).

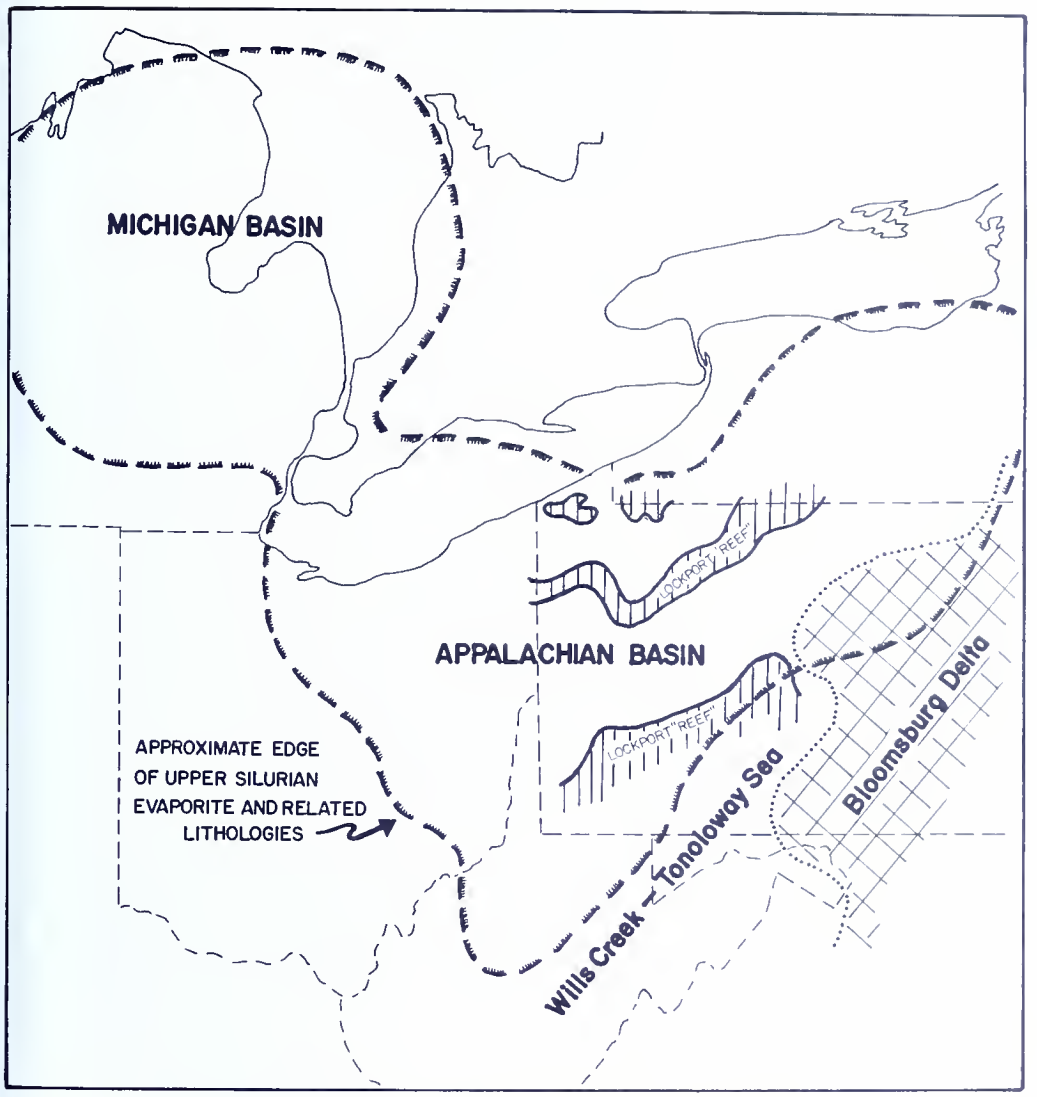


Figure 1. Depositional basins of Upper Silurian evaporites (after Alling and Briggs, 1961).

The reefs formed parallel to the perimeters of the Michigan and Appalachian Basins and prevented the interchange of sea water between the open sea and the reef-locked areas. The eastern extent of the salt beds in Pennsylvania was restricted by the influx of clastic material from the east on the margin of the basin.

Evaporation of sea water inside the reef-locked area resulted in the precipitation of primary dolomite, anhydrite, and halite with minor amounts of clastic material. Outside of the reef-locked areas carbonate rocks and marine shale beds were deposited.

The sea from which the Salina Group sediments were deposited transgressed over the Lockport Dolomite and Bloomsburg Formation from the west and northwest.

STRATIGRAPHY

The Cayugan Series of Late Silurian age consists of the Salina Group and the Bass Islands Group. The term Salina Group is restricted to those beds of Late Silurian age containing evaporitic sediments in the Michigan and Appalachian Basins.

During the past century many rock unit names have been applied to the Salina Group at the outcrop and in the subsurface sections causing the stratigraphic terminology to be diverse and confusing. Landes (1945) divided the Cayugan Series of the Michigan Basin into units based on the presence of salt beds. The units are designated by letters A through G with unit A being the basal unit. Unit H of Landes' terminology is equivalent to the Bass Islands Group. Subsequent work by Ulteig (1964) established Landes' terminology in northeastern Ohio adjacent to the Pennsylvania border.

In New York the Salina Group is often referred to as the Salina Formation which contains five members; Pittsford Shale, Vernon Shale, Syracuse Salt, Camillus Shale, and Bertie Waterlime (Wilmarth, 1938; Swartz, and others, 1942). When the Salina is referred to as a group the members achieve formational status. The lithology of the Salina Group in New York is similar to that of Pennsylvania, Ohio, and Michigan except in those areas where the lower red section of the Vernon Shale thickens and expands the entire group.

The Bloomsburg Formation lies beneath the Salina Group throughout the central part of Pennsylvania and extends eastward to the margin of the basin. The Bloomsburg is a wedge of essentially red clastic material derived from an eastern source and is equivalent to the lower red section of the Vernon Shale in New York.

According to Cate (1965), "The top of the Bloomsburg which is in contact with the Wills Creek is defined by the subtle distinction which exists between the mostly red color of the Bloomsburg and the mostly purplish-brown and greenish color of the Wills Creek." Following Cate, the green shales and interbedded carbonates of the Wills Creek were placed within units A, B, and C of the Salina Group in the areas where the facies change. The upper green section of the Vernon Shale is interpreted as being equivalent to the Greenfield Formation of Ohio or unit A of this report. The presence of anhydrite and anhydritic dolomite interbedded with the green section of the Vernon Shale lends support to the unit A designation. By placing the upper green section of the Vernon Shale and the lower Wills Creek facies equivalent at the base of the Salina Group, the red Vernon Shale and the Bloomsburg Formation are excluded from the Salina Group.

The Bass Islands Group in Pennsylvania is between 70 and 150 feet thick and consists of a sequence of dolomitic limestone and calcareous

dolomite located between the chert-bearing limestones of the overlying Devonian Helderberg Group and the evaporite beds of the underlying Salina Group. The Bass Islands is usually present as a brown, argillaceous, calcareous dolomite or dolomitic limestone. The basal 30 to 50 feet are usually very argillaceous and referred to as dolomitic shale.

DESCRIPTION OF THE SALINA GROUP UNITS

Unit A

Unit A ranges in thickness from 50 feet in the western part of Pennsylvania in Mercer and Fayette Counties to over 500 feet in Bradford County. The unit is over 400 feet thick in Bedford and Blair Counties and may be considered equivalent to or part of the Wills Creek Formation (Fig. 2).

The unit is commonly called the Greenfield Formation in Ohio where it consists of pale green and light gray, sandy shale with some thin beds of anhydrite and gypsum. The thickest occurrences of unit A beds in Ohio and Pennsylvania correspond to thin areas of underlying Lockport Dolomite (Fig. 3). The thick sections of Lockport Dolomite appear to enclose basins in which the thicker unit A beds were deposited.

The upper surface of the Bloomsburg Formation in central and eastern Pennsylvania represents the basal contact of the Salina Group. The contact between unit A sediments and the underlying shale beds is easily recognizable on geophysical well logs. In western Pennsylvania the Bloomsburg Formation is absent and the lower limit of unit A is placed at the base of the lowest anhydrite bed above the Lockport Dolomite of the Niagaran Series.

The lithofacies map of unit A (Fig. 4) shows a decrease in the clastic content of unit A sediments from east to west indicating that the eastern area was still under the influence of the provenance that supplied the clastic material of the underlying Bloomsburg Formation. Dolomite and shale were being deposited in the western and central part of the State from a sea that appeared to be transgressing from the west. There are no unit A salt beds in Pennsylvania.

The upper boundary of unit A is placed beneath the lowest salt bed or its anhydritic equivalent in overlying unit B.

Unit B

Unit B contains the first salt beds of the Salina Group deposited in Pennsylvania. This unit, however, does not contain salt in all areas. Unit B ranges in thickness from 109 feet in Erie County to 758 feet in Tioga County (Fig. 5). The unit B isopach map indicates the development of a basin in north-central Pennsylvania with terracelike areas in

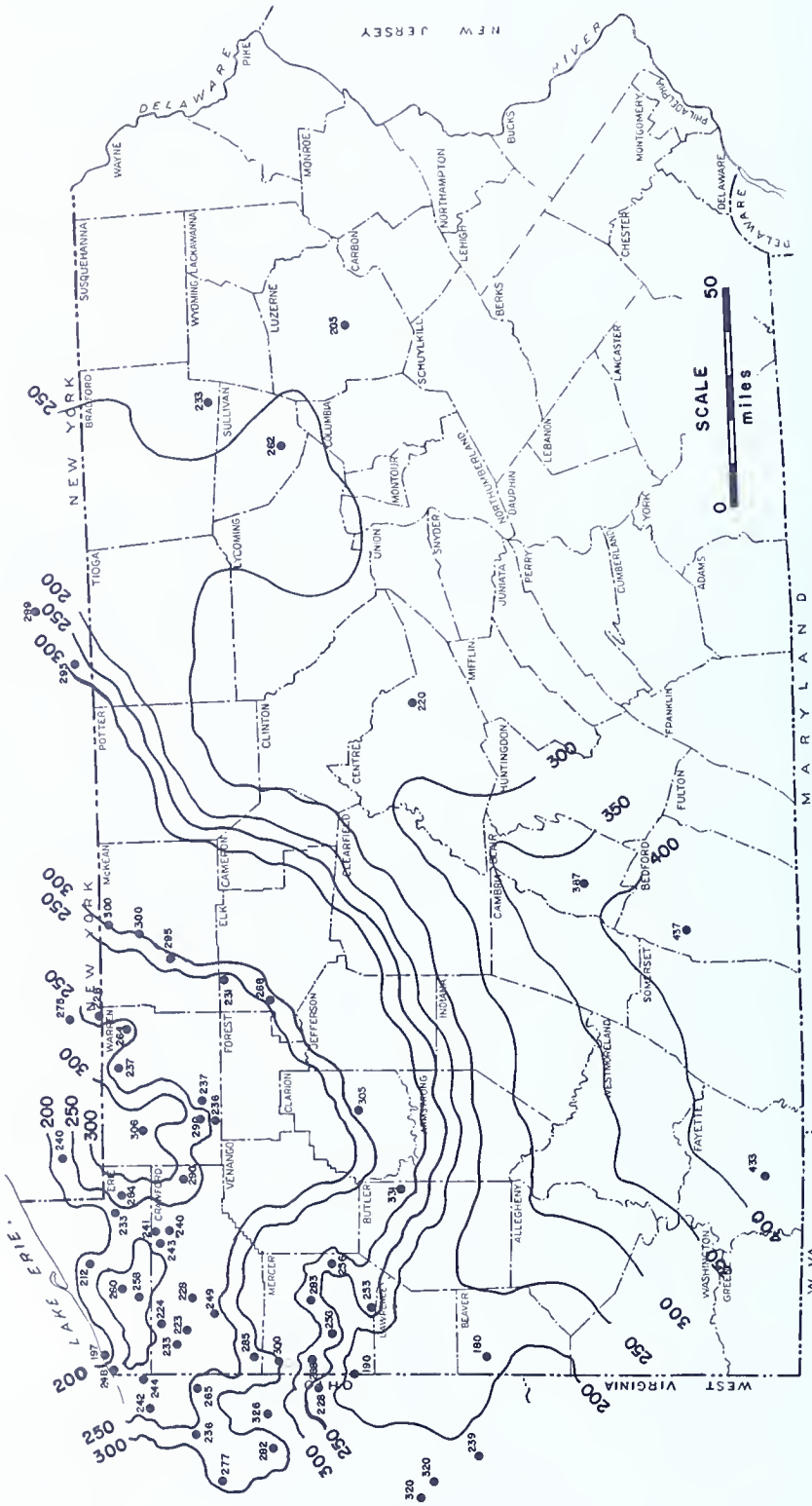


Figure 2. Isopach map of the Lockport Dolomite.

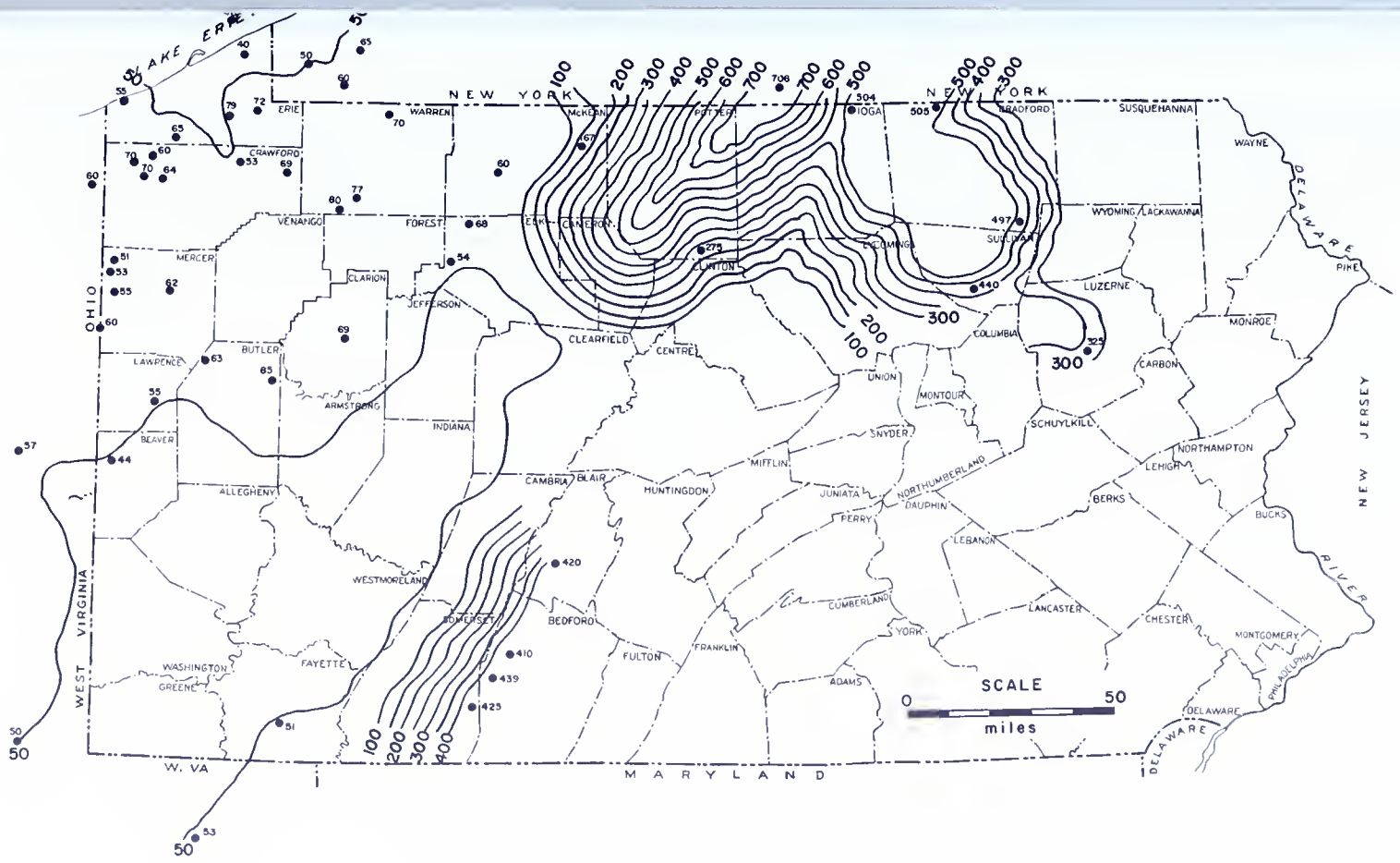


Figure 3. Isopach map of Unit A.

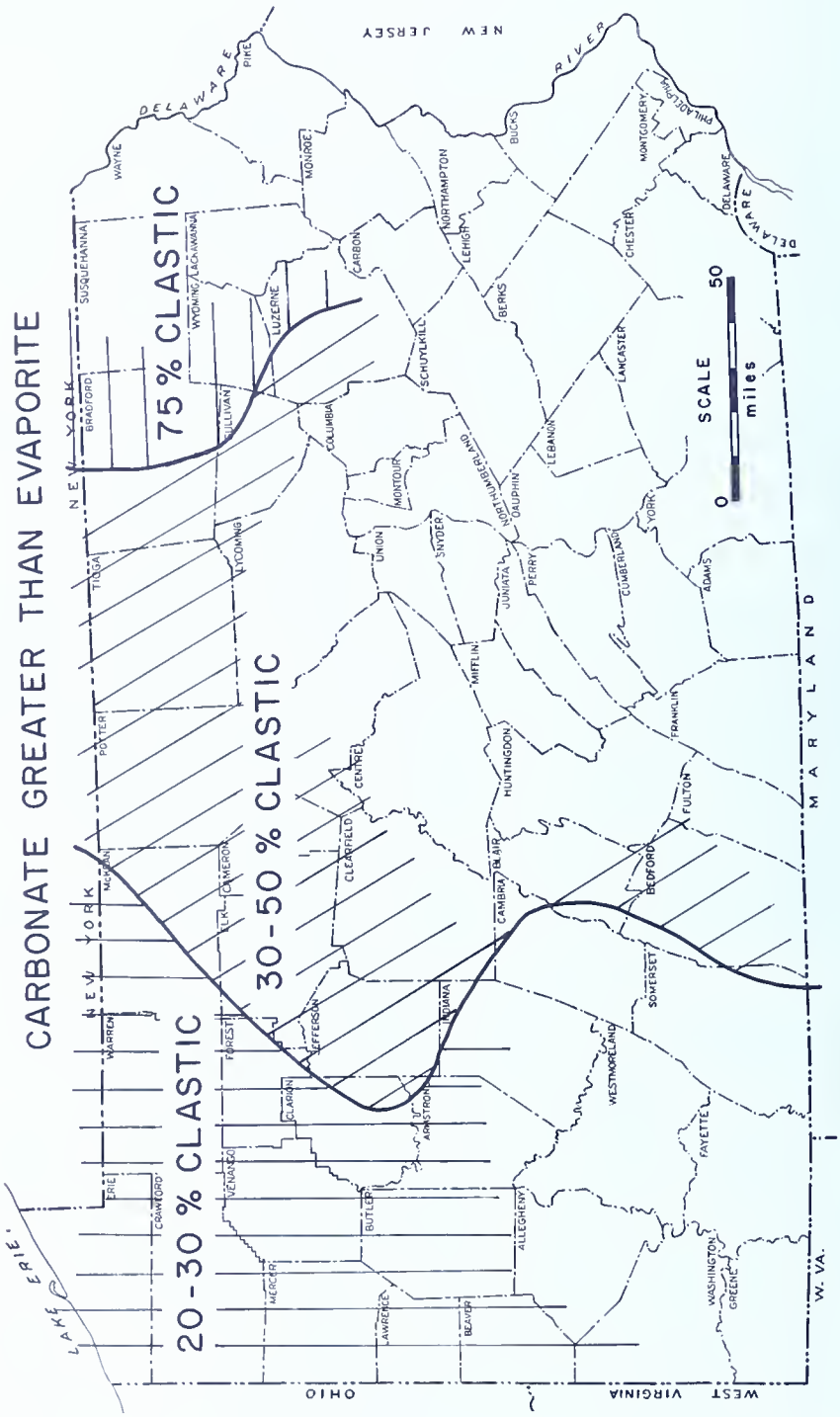


Figure 4. Lithofacies map of Unit A.

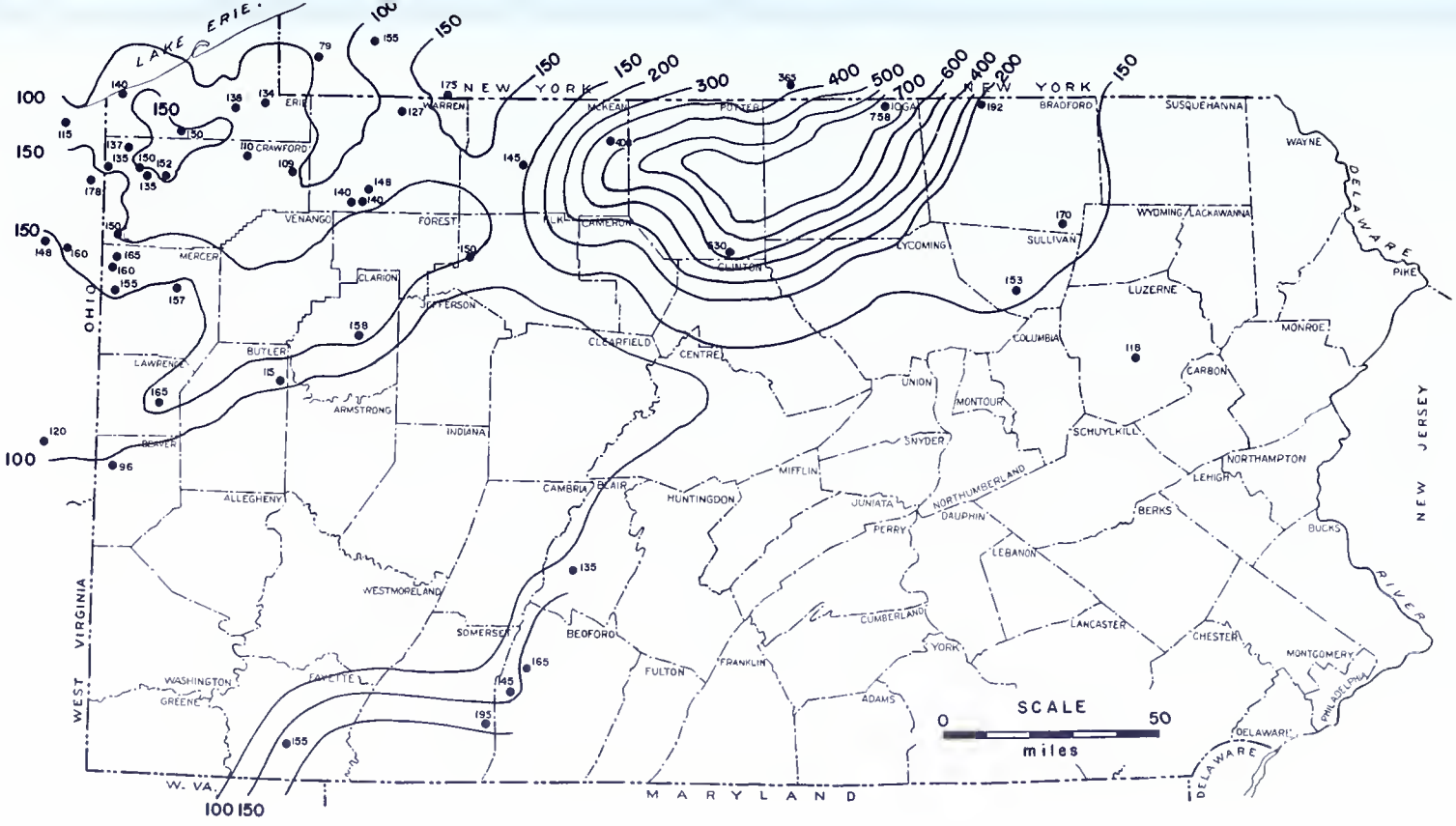


Figure 5. Isopach map of Unit B.

the north and southwestern regions containing thin sections of unit B sediments. The thin southwestern section increases in thickness to the east in Bedford and Somerset Counties where the junction between the Salina and Wills Creek Basins is located.

The salt beds are thin and form a sinuous ribbonlike pattern across northwestern Pennsylvania before connecting with the thicker basin deposits in the north-central area (Fig. 6). The unit B salt is usually contained in two beds separated by 10 to 50 feet of thin shale, anhydrite, and dolomite.

The evaporite portion of unit B is restricted to northern Ohio, northeastern and north-central Pennsylvania, and southern New York. There appears to be an intimate association between the Lockport Dolomite of the Niagaran Series and the deposition of salt. The Niagaran Series is well known for the reef structures it contains. If the thicker portions of the Lockport Dolomite are considered to be reefs (Fig. 2) and the boundaries of the reefs are plotted with the zero isopach line of the unit B salt a strong parallelism is noted between the reef margins and the edge of the salt (Fig. 7). The salt is stratigraphically higher than the reef margins but probably close laterally because of a draping effect over the reefs. As noted previously, thinner parts of unit A are associated with the thicker parts of the Lockport Dolomite and it was suggested that the thicker unit A sediments were deposited inside basinlike areas of Lockport Dolomite. It appears that the salt beds of unit B were also deposited inside the reefs in northwestern Pennsylvania. The salt beds in the north-central region were deposited in the larger basin which is bounded by a reef on the west, and associated with the edge of the Bloomsburg delta and high clastic content of unit A on the east (Fig. 1).

Salt deposition did not occur in the thin sedimentary section in southwestern Pennsylvania. This thin, or high, region limits the southern edge of salt deposition as well as the large southwesternmost reef. There are no evaporite beds behind the large southwestern reef in the Cambria and Blair County area where the Wills Creek sea lay to the southeast of the high unit A area and this southernmost reef.

The pattern of evaporite deposition within the Salina sediments (Fig. 8) was probably fixed by the location of the Niagaran reefs, the inland or eastward restriction of the Bloomsburg delta, and the thin or high area of southwestern Pennsylvania. This early established environmental pattern prevailed throughout most of Salina deposition.

Unit C

The unit C well samples usually consisted of gray to green shale and dolomitic anhydrite, but in many cases the entire unit is composed of argillaceous dolomite. Unit C ranges in thickness from 17 feet in Erie County to 150 feet in Potter County (Fig. 9).

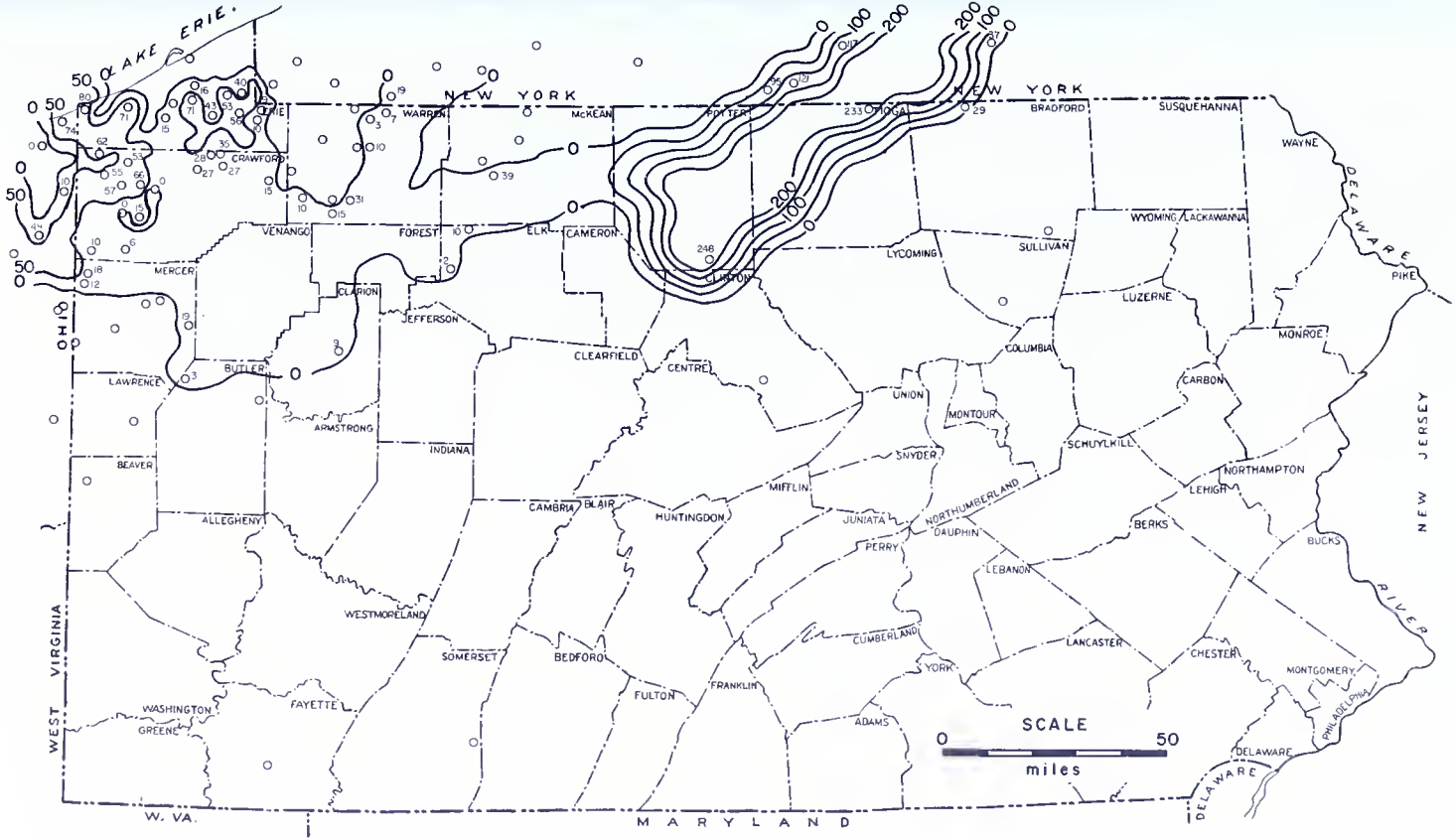


Figure 6. Thickness of salt in Unit B, contour interval 50 feet.

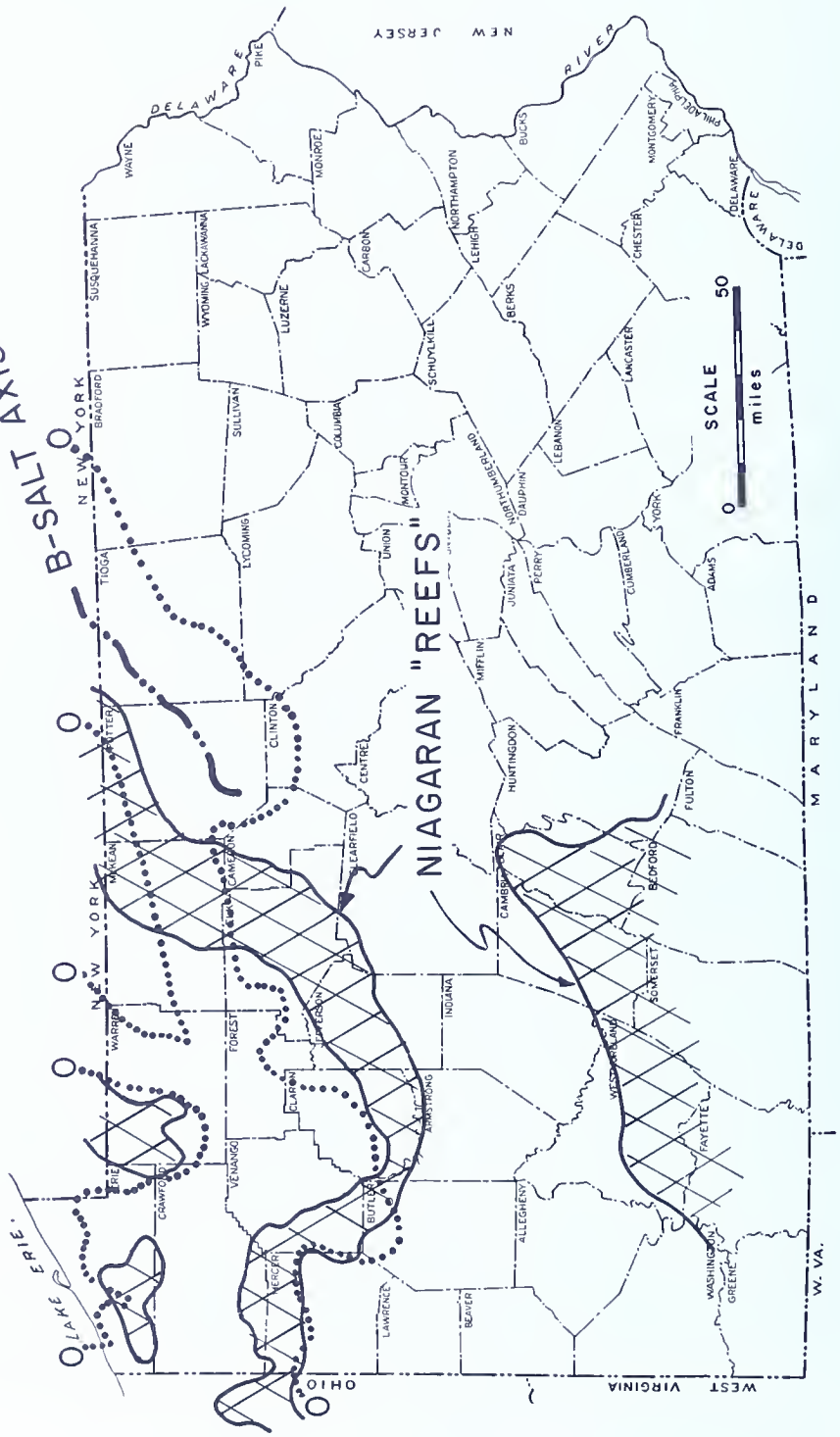


Figure 7. Relation of reef margin to salt thickness in Unit B.

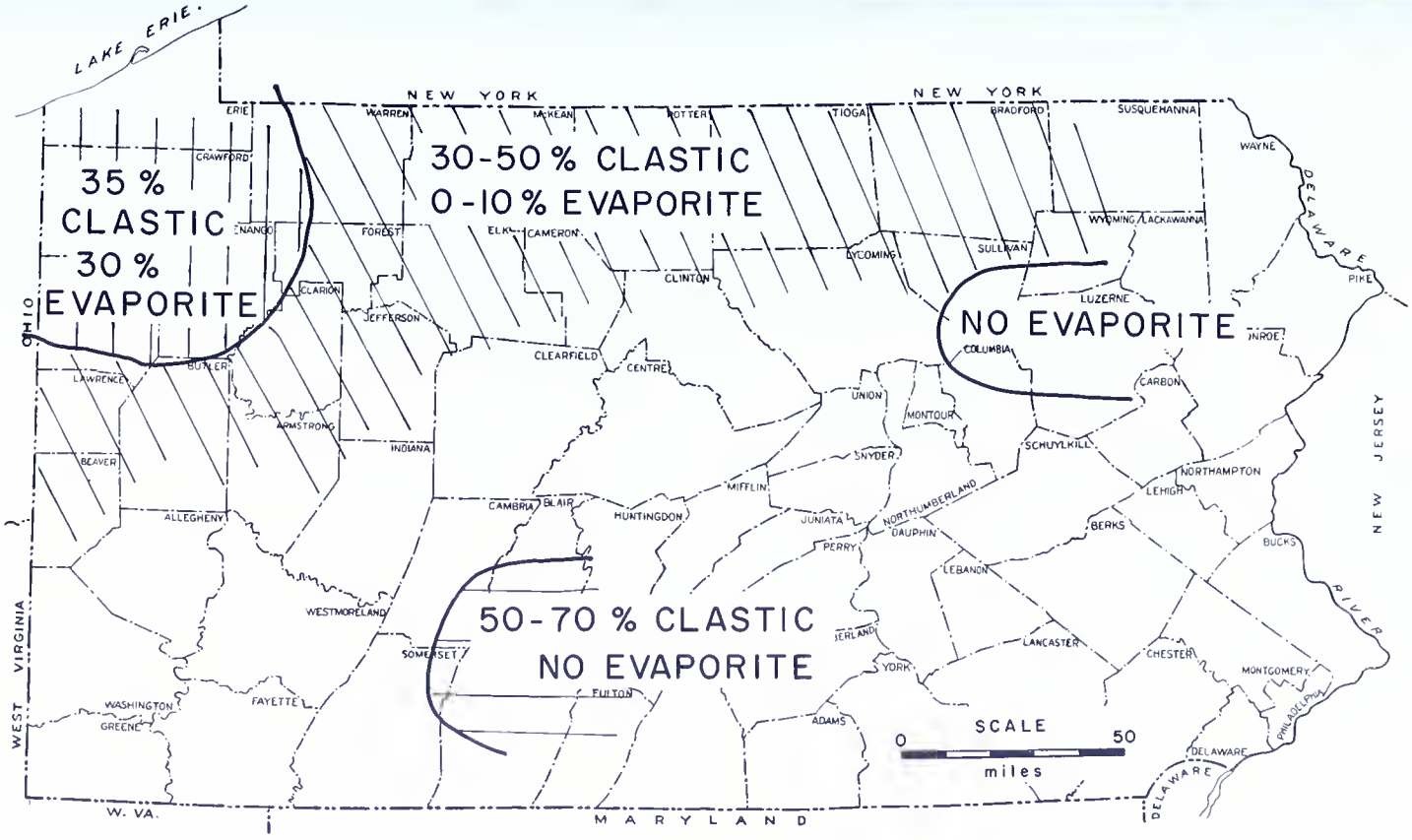


Figure 8. Lithofacies map of Unit B.

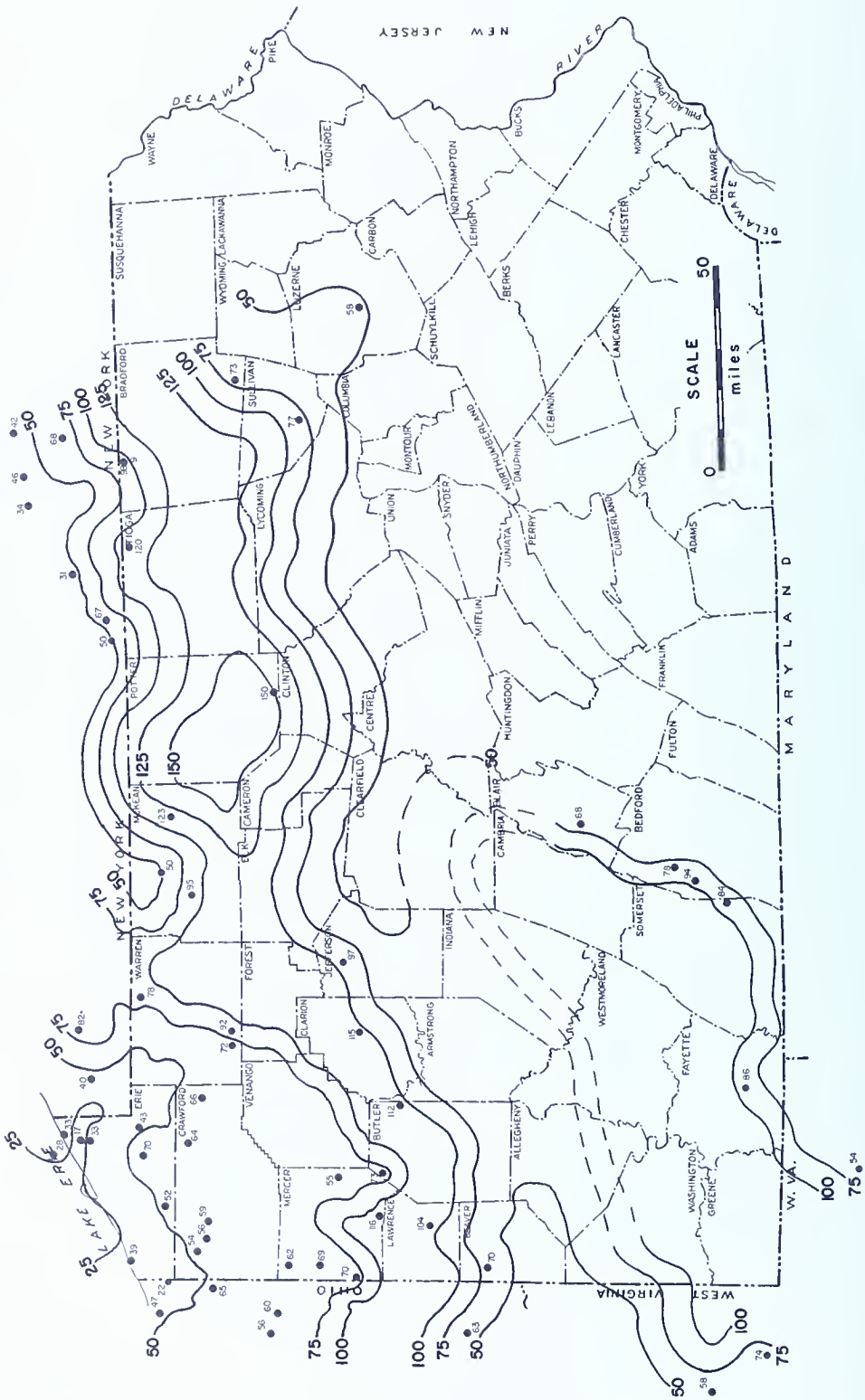


Figure 9. Isopach map of Unit C.

Unit C has the highest radioactive intensity of all the Salina Group units and is easily identifiable on gamma ray–neutron well logs. The upper boundary of the unit may be recognized by the lithologic change from the overlying evaporite beds of unit D to the argillaceous beds of unit C. In many cases a sandstone bed, about 6 feet thick, marks the base of unit D. This bed also provides an excellent lithologic contrast between units C and D.

There are no salt beds in unit C. The isopach map (Fig. 9) shows the continuance of the basin in north-central Pennsylvania and the thin platform areas in northwestern and southwestern Pennsylvania.

The lithofacies map (Fig. 10) indicates that the clastic material of the gray to green shale and the argillaceous fraction of the dolomite make up from 35 to 75 percent of the section. The least clastic section or more carbonaceous section is to the east of the north-central basin.

Unit D

This unit is thin in the southwestern region, platformlike in the northwest, and has a basin in the north-central region (Fig. 11). Unit D is salt bearing and the salt attains a thickness of greater than 200 feet in the north-central basin (Fig. 12).

The depositional pattern (Fig. 13) and thickness of the salt is essentially similar to that of the unit B salt except the southern margin of the salt has shifted to the southeast. The salt deposits are still within the bounds established by the Niagaran reefs, the Bloomsburg delta, and the high or thin section in the southwest.

Unit D is easily recognizable in gamma ray well logs because of its low radioactive intensity between the higher radioactive intensity of the shale and carbonate sections of underlying unit C and overlying unit E. Stratigraphic position, lithology, and geophysical well log characteristics of unit D indicate the equivalence of the Pennsylvania section with similar unit D sections in Ohio and Michigan.

Unit E

Unit E ranges between 94 feet thick in Erie County to 270 feet in Jefferson County (Fig. 14). The thickness of the deposits indicate that the unit is similar to the previous units in being platformlike in the northwest and southwest, but the thickness axis of the north-central region has shifted to the south and west. The salt beds are thin and never attain a thickness greater than 37 feet (Fig. 15). The salt beds are located on the border between the northwestern platform area and the deeper basin in Jefferson and Elk Counties.

The lithology of unit E (Fig. 16) is varied but is always marked by an upper shale bed of high radioactive intensity below which interbedded anhydrite, dolomite, and a thin sporadic salt bed occur.

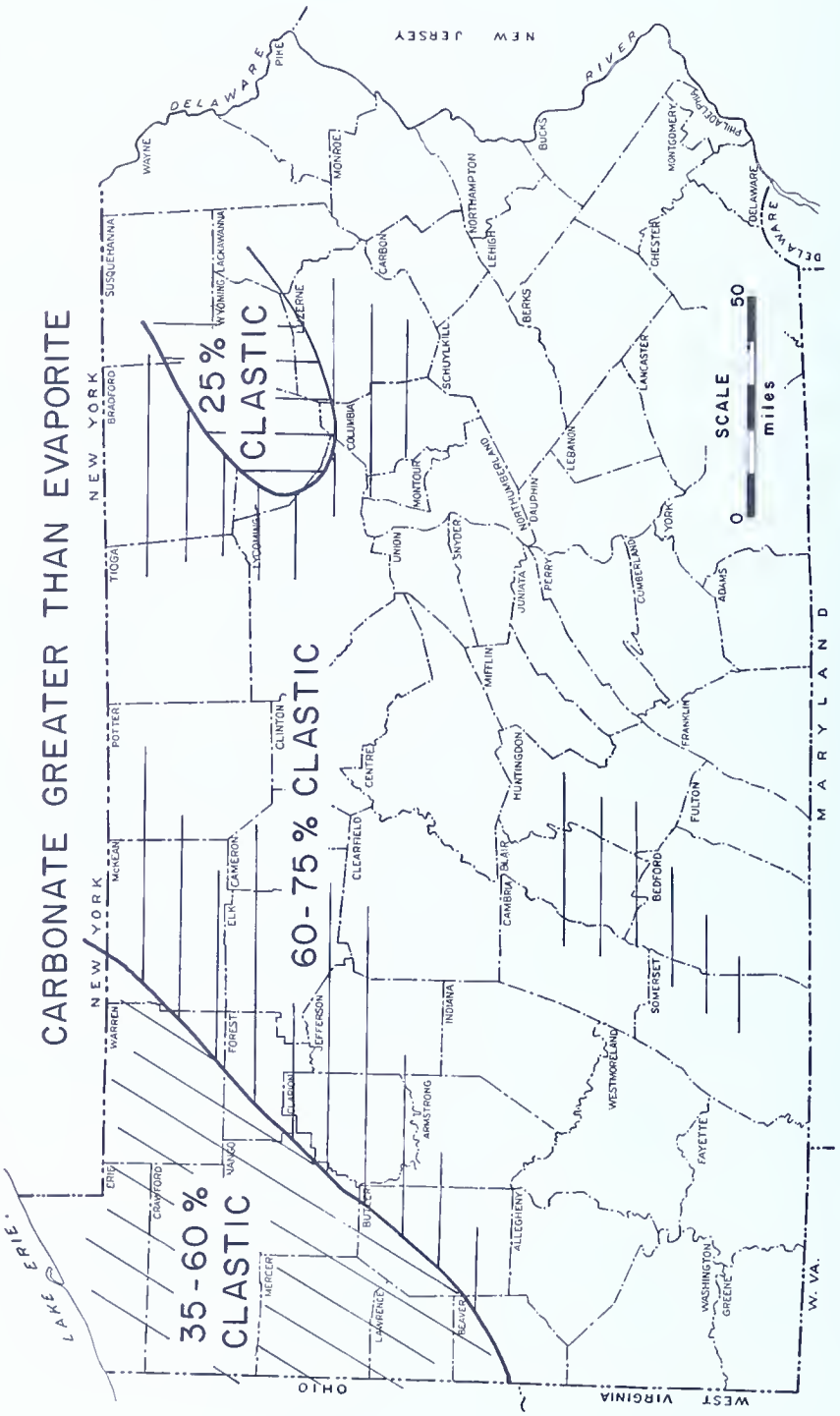


Figure 10. Lithofacies map of Unit C.

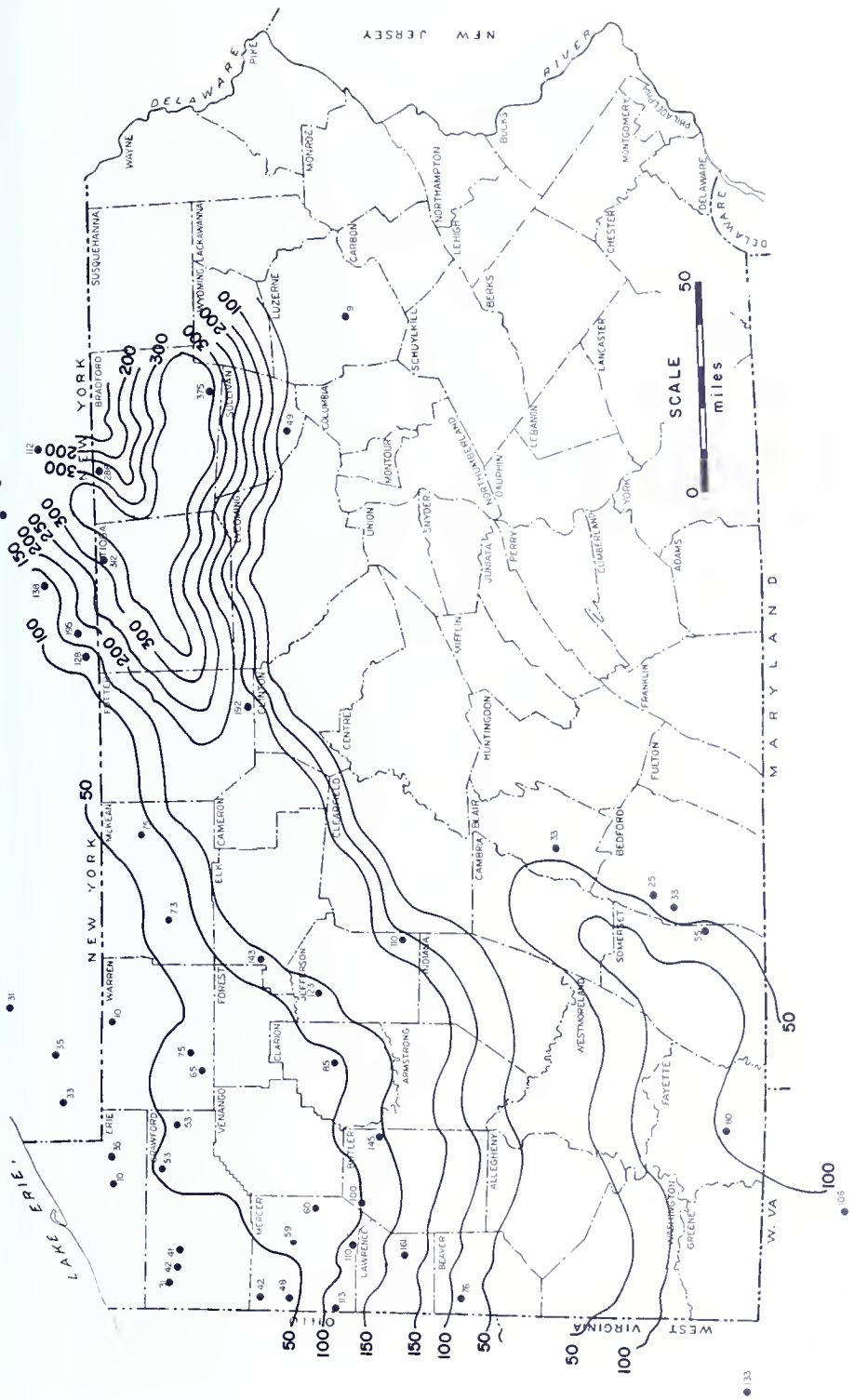


Figure 11. Isopach map of Unit D.

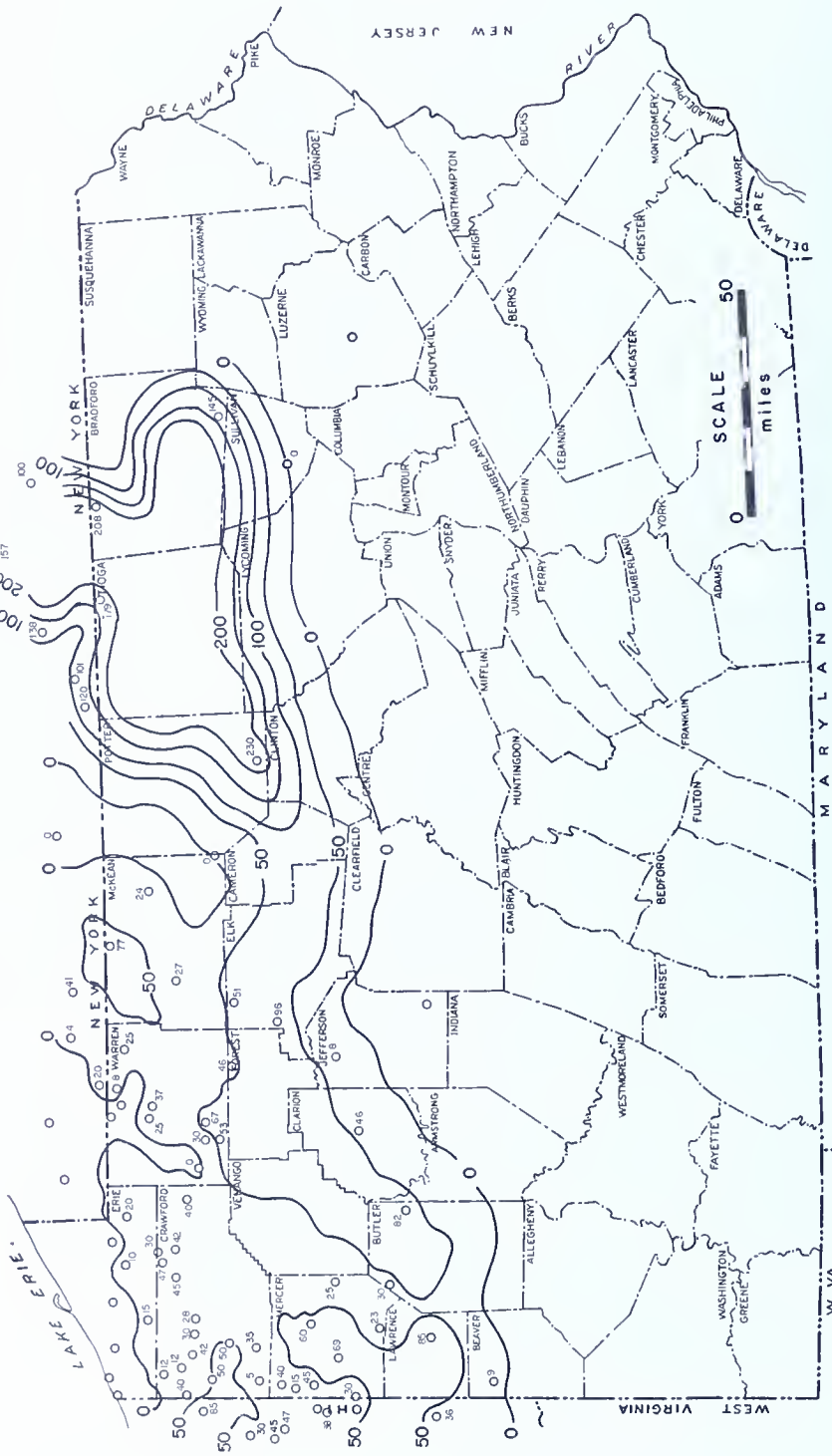


Figure 12. Thickness of salt in Unit D, contour interval 50 feet.

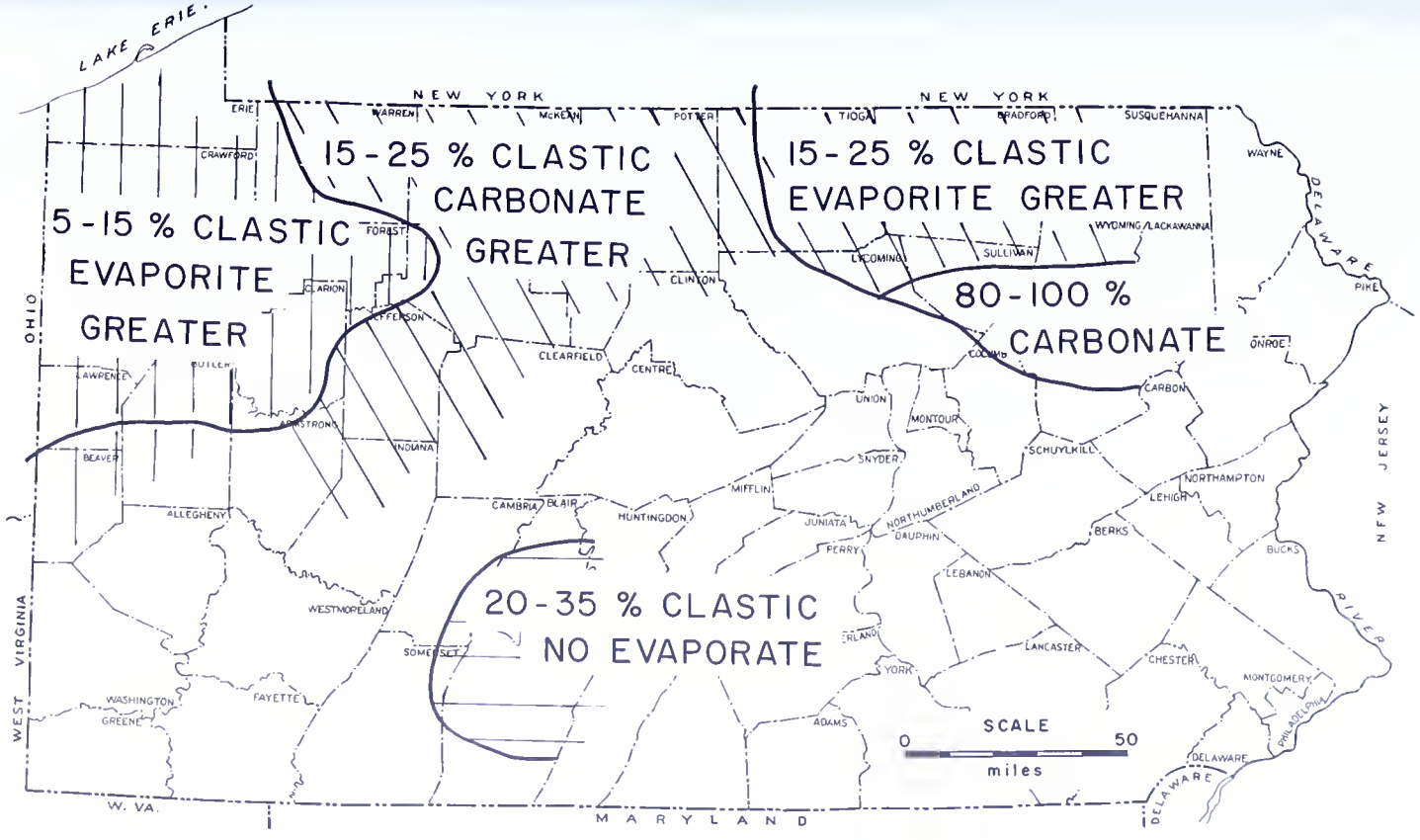


Figure 13. Lithofacies map of Unit D.

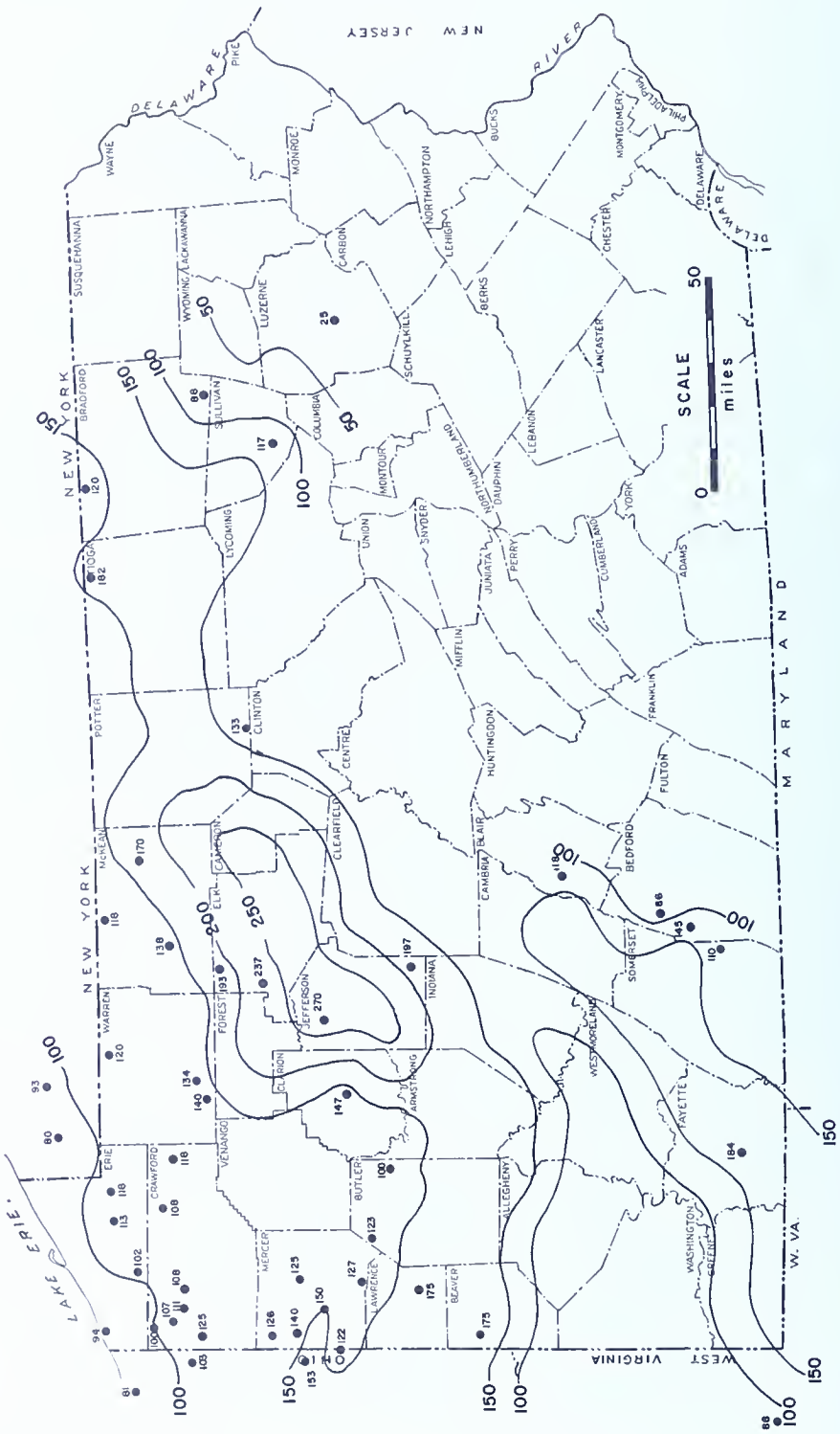


Figure 14. Isopach map of Unit E.

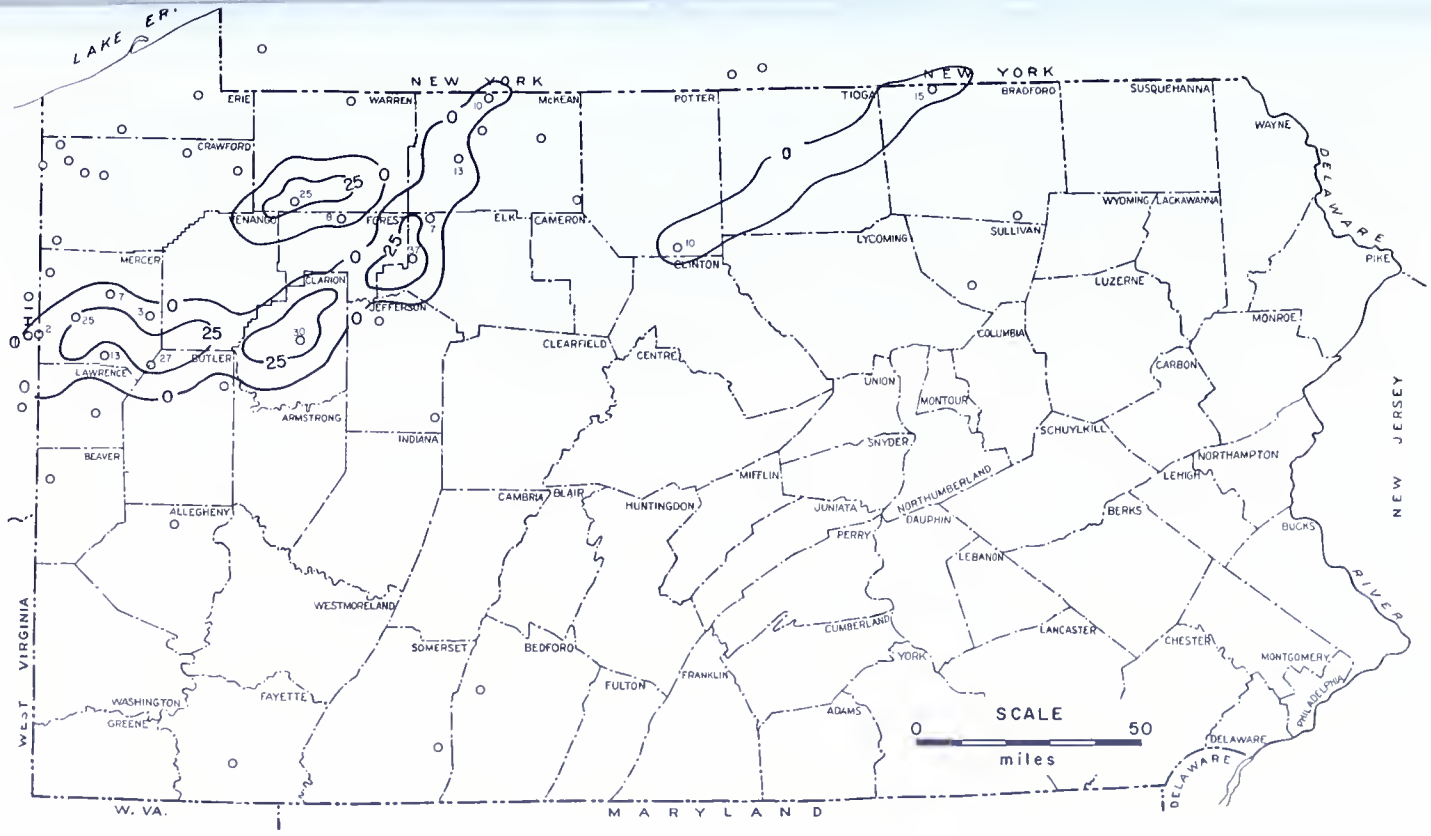


Figure 15. Thickness of salt in Unit E, contour interval 25 feet.

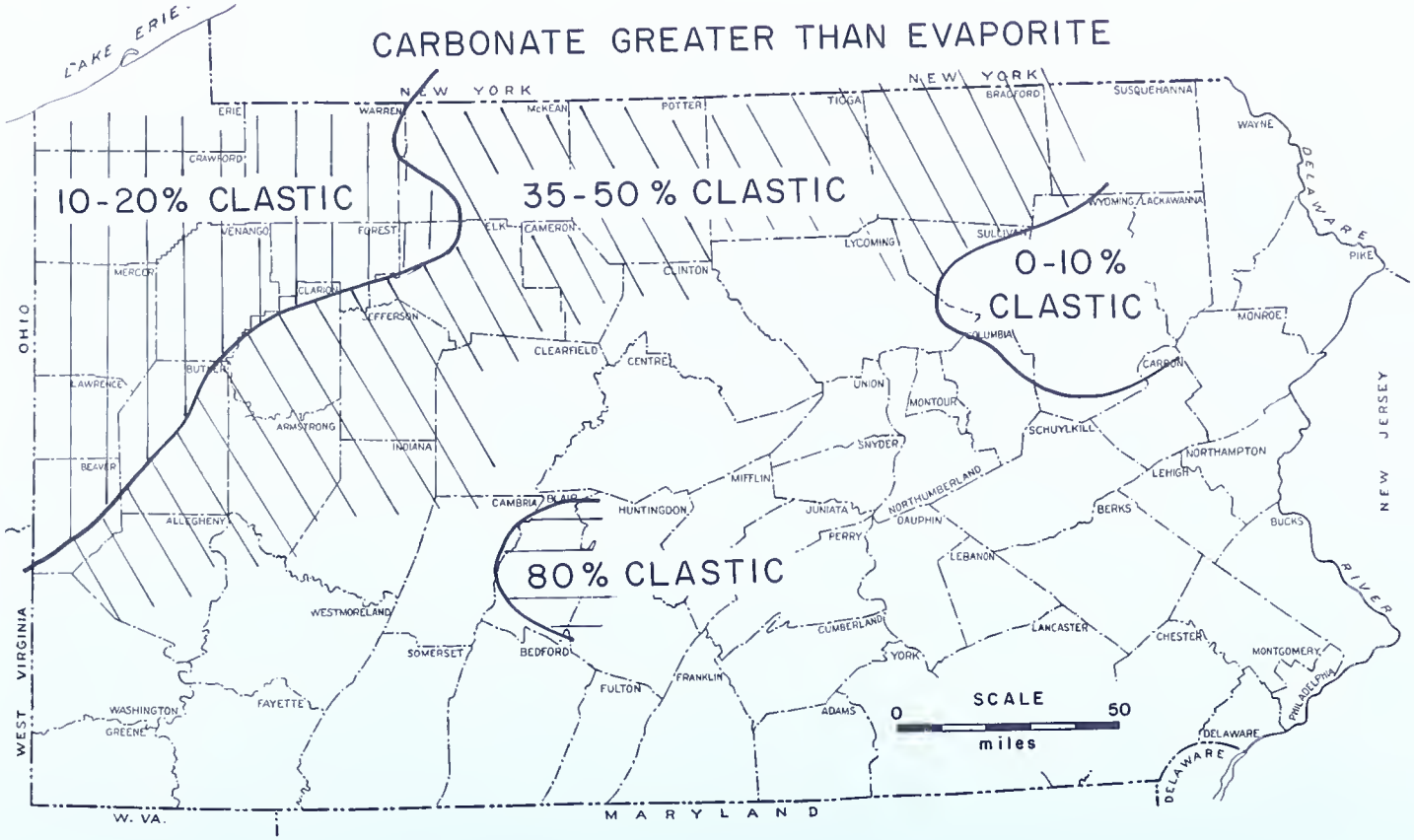


Figure 16. Lithofacies map of Unit E.

Unit F

Unit F is the thickest of the Salina Group units and ranges from 64 feet in Erie County to 890 feet in Bradford County, and reaches a maximum thickness of 1,305 feet in Fayette County (Fig. 17).

Unit F consists of thick salt beds (Figs. 18, 19, 20, Plate 1) which are separated by beds of dolomite, argillaceous dolomite, and dolomitic shale. Ells (1962) defined six distinct salt-bearing sections within Unit F which he designated numerically 1 through 6 in ascending order. In Pennsylvania, unit F salt beds are the lowest three of the Michigan beds. The upper three salt beds are represented by an anhydrite equivalent or are missing. The unit F-4 salt bed may be present in northeastern Bradford County.

The lower boundary of unit F is the contact between the lowest evaporite of unit F and the underlying upper shale bed of unit E (Fig. 21). The upper boundary of unit F is placed at the base of the overlying dolomite of unit G.

The unit F-1 salt occurs within the same area of deposition as the previous salt beds of units B and D. There has been a further shift of the southern margin of the salt to the southeast which has left the northwestern region of the State more calcareous than evaporitic with no salt deposits in Erie and parts of Crawford County.

The zero isopach of unit F-2 salt has migrated still further to the southeast, and a thick layer of salt was deposited in southwestern Pennsylvania (Fig. 19). The salt beds of unit F-2 represent the first occurrence of evaporites in the southwestern region, and the thickest section to be deposited in the area during Salina Group deposition.

The continual migration of the southern zero isopach of the salt beds of units B, D, F-1, and F-2 in a southeasterly direction and the consequent migration of the northern zero isopach appears to indicate the presence of a hinge line in the northwest, probably in the Lake Erie area. The entire area was continually being tilted to the southeast throughout the deposition of the Salina beds with maximum tilting occurring during or just prior to the deposition of the unit F-2 salt beds as witnessed by the extension of the salt deposits into the previously high or thin southwestern region.

The salt-thickness map of unit F-3 salt (Fig. 20) indicates a lessening of the southeast tilting of the area with salt being deposited within the areas of the units B, D, F-1, and northerly F-2 salt beds. The unit F-3 salt represents the last major deposition in Pennsylvania.

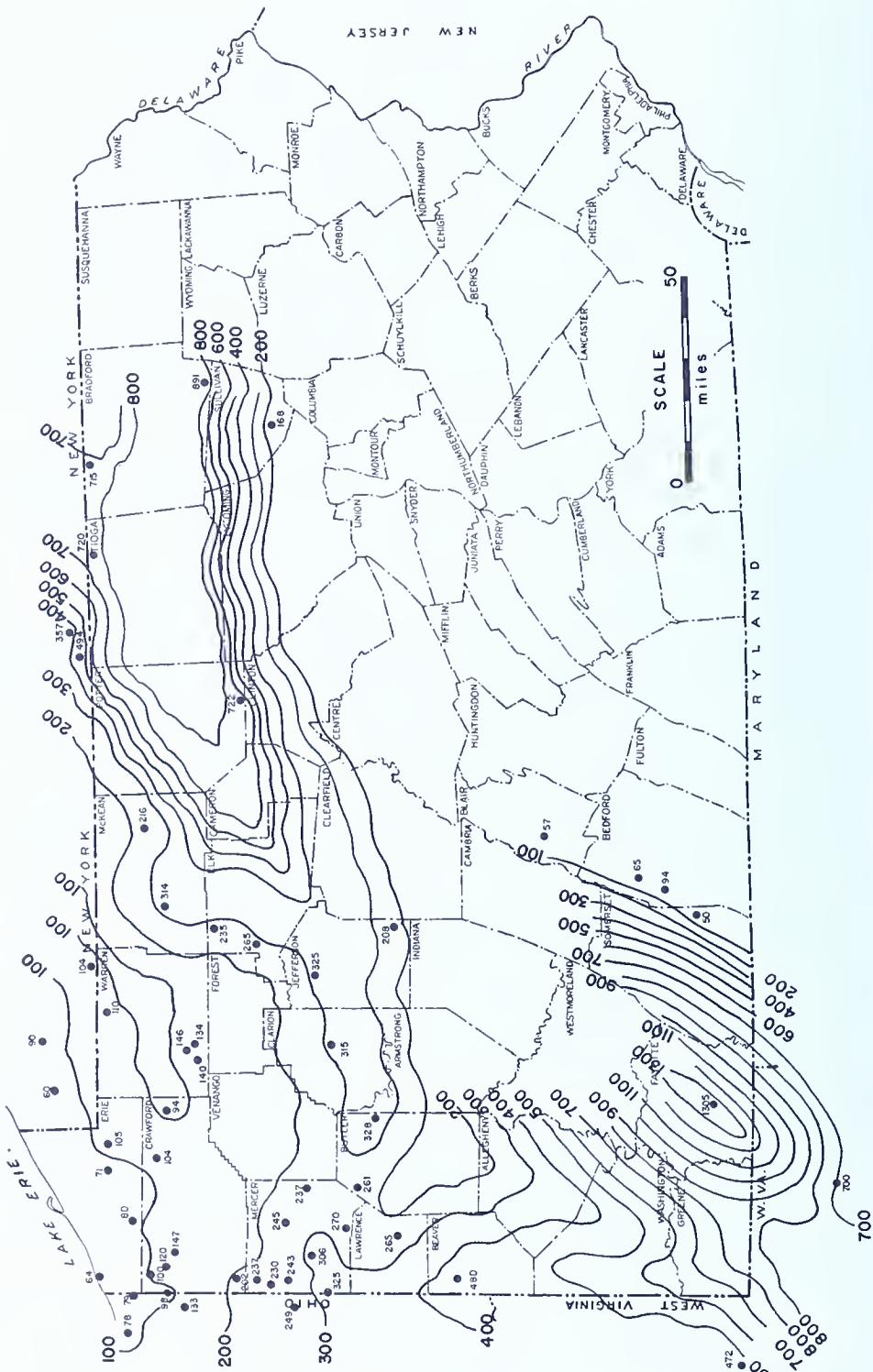


Figure 17. Isopach map of Unit F.

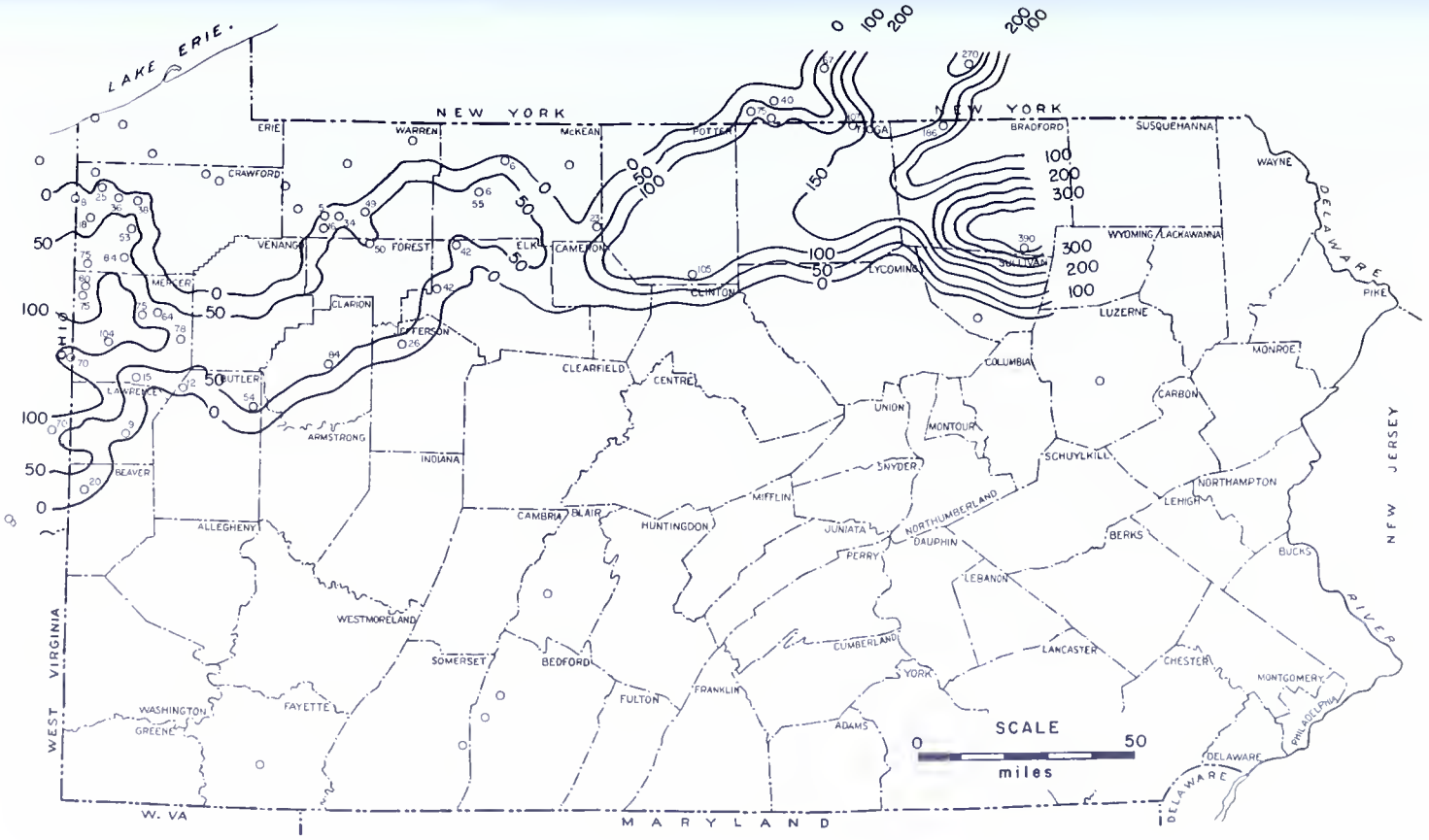
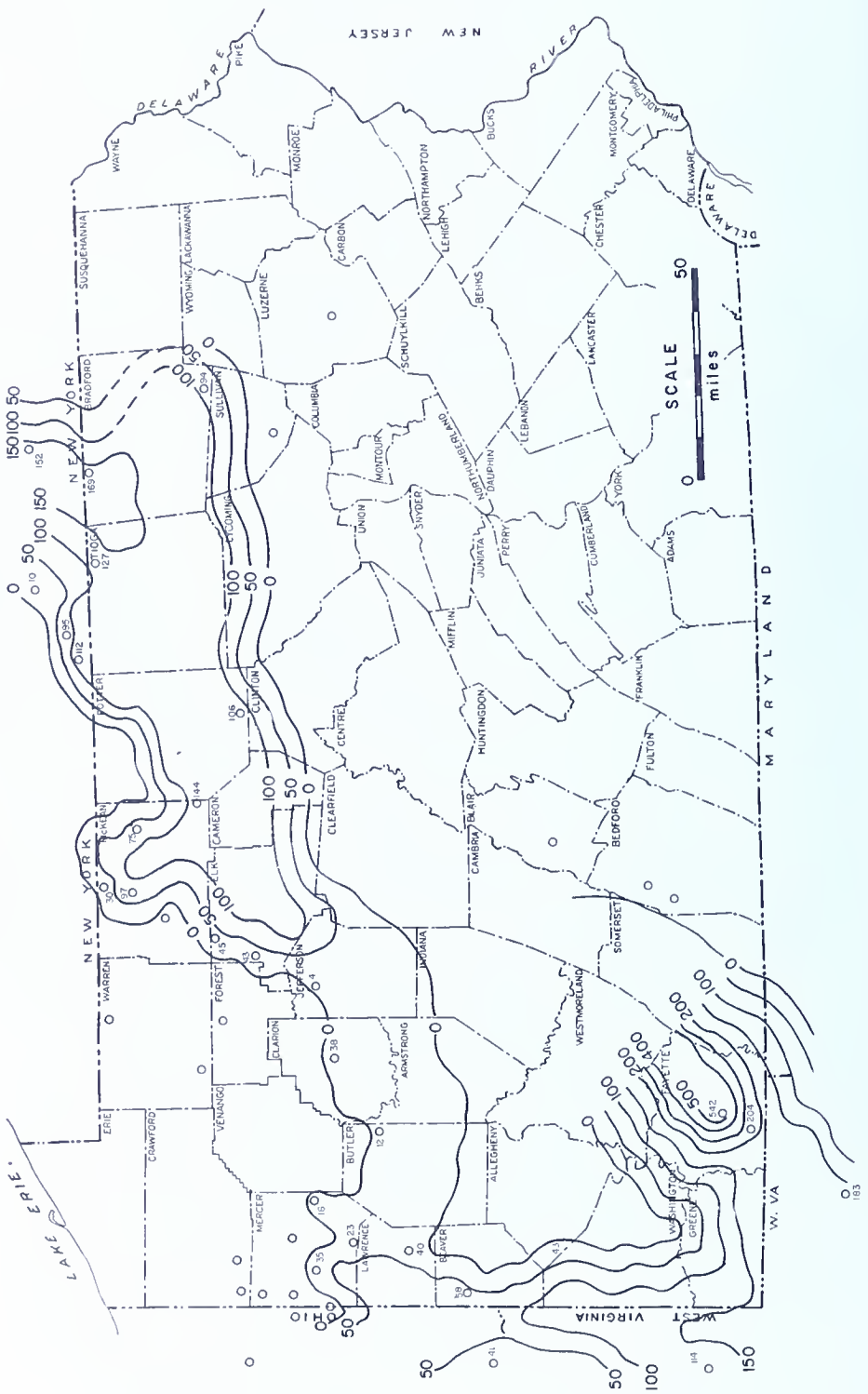


Figure 18. Thickness of salt in Unit F-1, contour interval 50 feet.


LAKE ERIE
NEW YORK
NEW JERSEY
DELAWARE RIVER
MARYLAND
W. VA
VIRGINIA
SCALE
50
0
miles
ERIE
CRAWFORD
MERCER
VENANGO
WARREN
FOREST
CLARION
BUTLER
ARMSTRONG
LAWRENCE
BEAVER
ALLEGHENY
WESTMORELAND
INDIANA
JEFFERSON
CAMERON
ELK
CLEARFIELD
CENTRE
CLINTON
CAMBRIA
BLAIR
HUNTINGDON
MIFFLIN
JUNIATA
PERRY
SNYDER
UNION
MONTOUR
COLUMBIA
SULLIVAN
WYOMING
LUZERNE
SUSQUEHANNA
WAYNE
PIKE
MONROE
CARBON
SCHUYLKILL
NORTHUMBERLAND
DAUPHIN
LEBANON
LANCASTER
YORK
ADAMS
CUMBERLAND
FRANKLIN
FULTON
BEDFORD
SOMERSET
WASHINGTON
GREENE
FAYETTE
NORTHAMPTON
LEHIGH
BERKS
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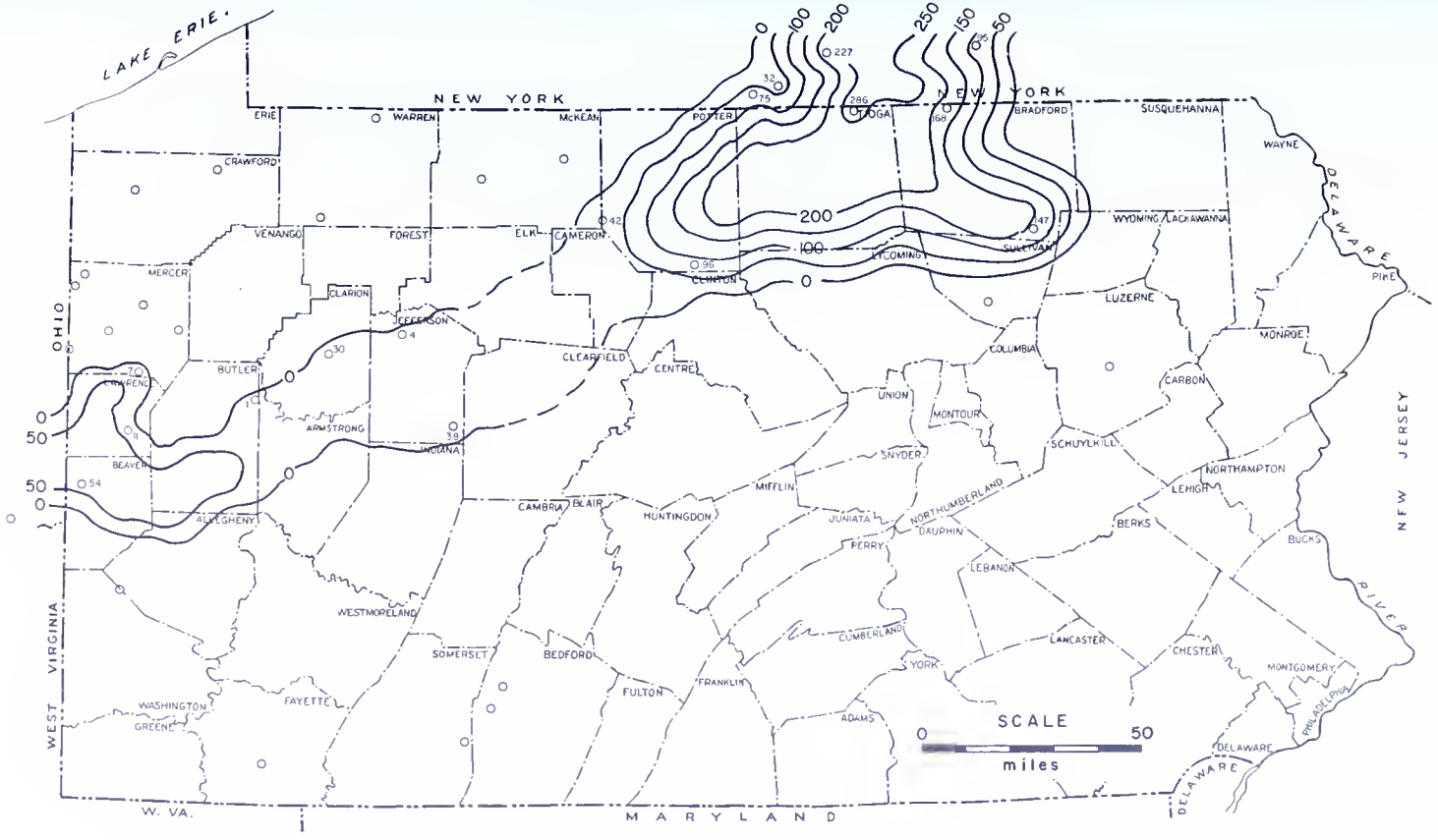

Figure 20. Thickness of salt in Unit F-3, contour interval 50 feet.

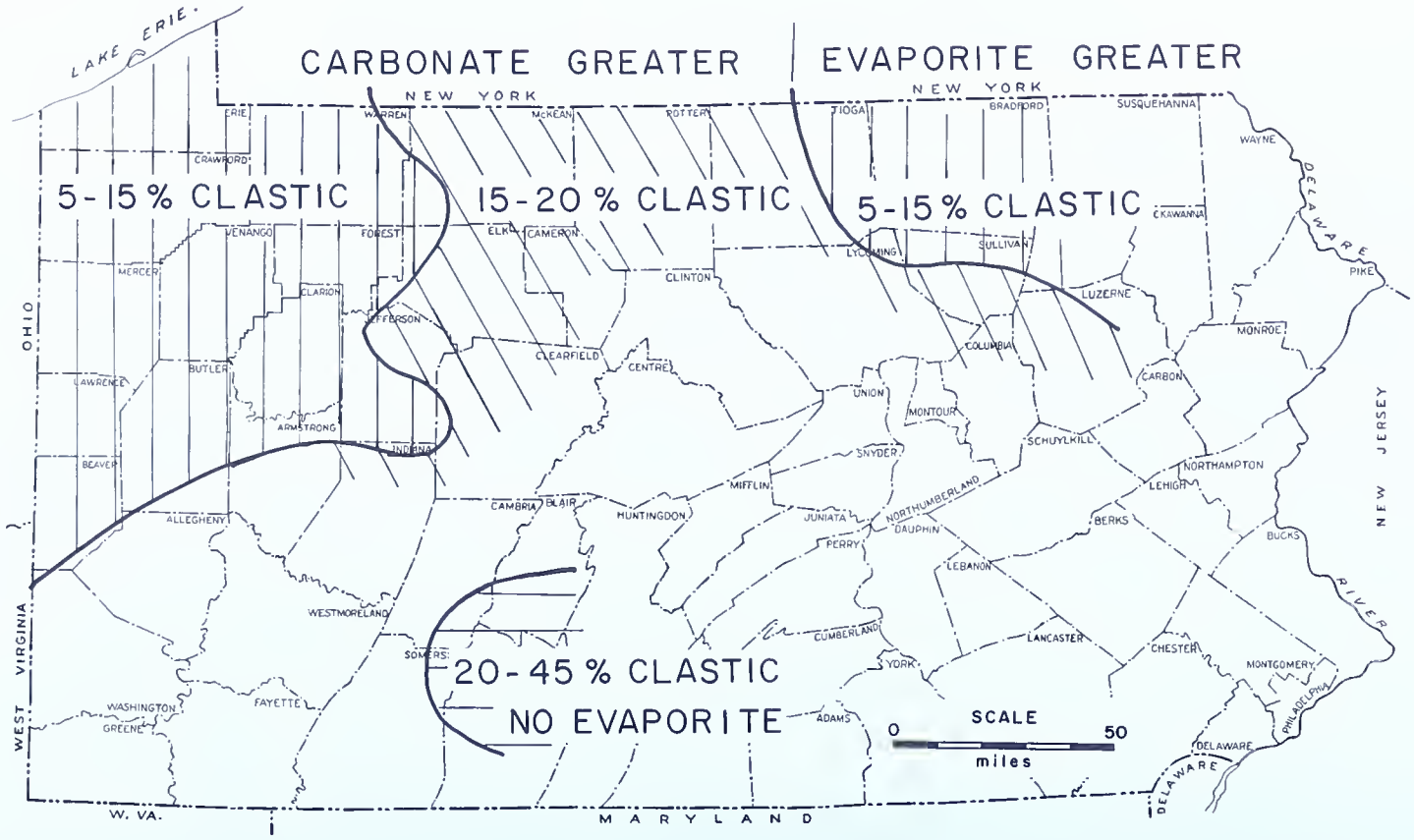

Figure 21. Lithofacies map of Unit F.

Unit G

Unit G occupies the interval between the uppermost salt beds of unit F and the overlying carbonate beds of the Bass Islands Group. The unit is thin but basins are still indicated in north-central and southwestern Pennsylvania (Fig. 22).

The lithologies of unit G are calcareous dolomite and some anhydrite beds. The anhydrite beds are at the top of the unit and mark the uppermost boundary of the Salina Group.

The lithofacies map (Fig. 23) and the isopach map (Fig. 22) indicate further tilting of the area to the southeast with an excess of flooding that resulted in the deposition of calcareous dolomite with a low clastic content and some bedded anhydrite.

Bass Islands Group (Unit H)

The isopach map of the Bass Islands Group (Fig. 25) shows only a vestige of the north-central basin and the southwestern basin in which the unit F-2 salt and unit G beds were deposited.

The Bass Islands Group lies beneath the Shriver and Helderberg beds which are below the Oriskany Sandstone. The unconformity at the base of the Oriskany Sandstone has removed the Shriver, Helderberg and part of the Bass Islands Group in some areas. In the areas where the Helderberg Group overlies the Bass Islands the upper boundary of the Bass Islands, or Silurian System, is arbitrarily placed at the first occurrence of dolomite below a medium to coarsely crystalline limestone. This boundary as well as being arbitrary is open to much interpretation because the Bass Islands Group sometimes contains limestone beneath its upper dolomite beds.

The Bass Islands Group as represented in this paper is much thinner than indicated by other workers. This is because the Keyser Limestone in the central and southern part of Pennsylvania has been omitted from the Silurian sequence as a result of the Lower Devonian affinities of the Keyser fauna.

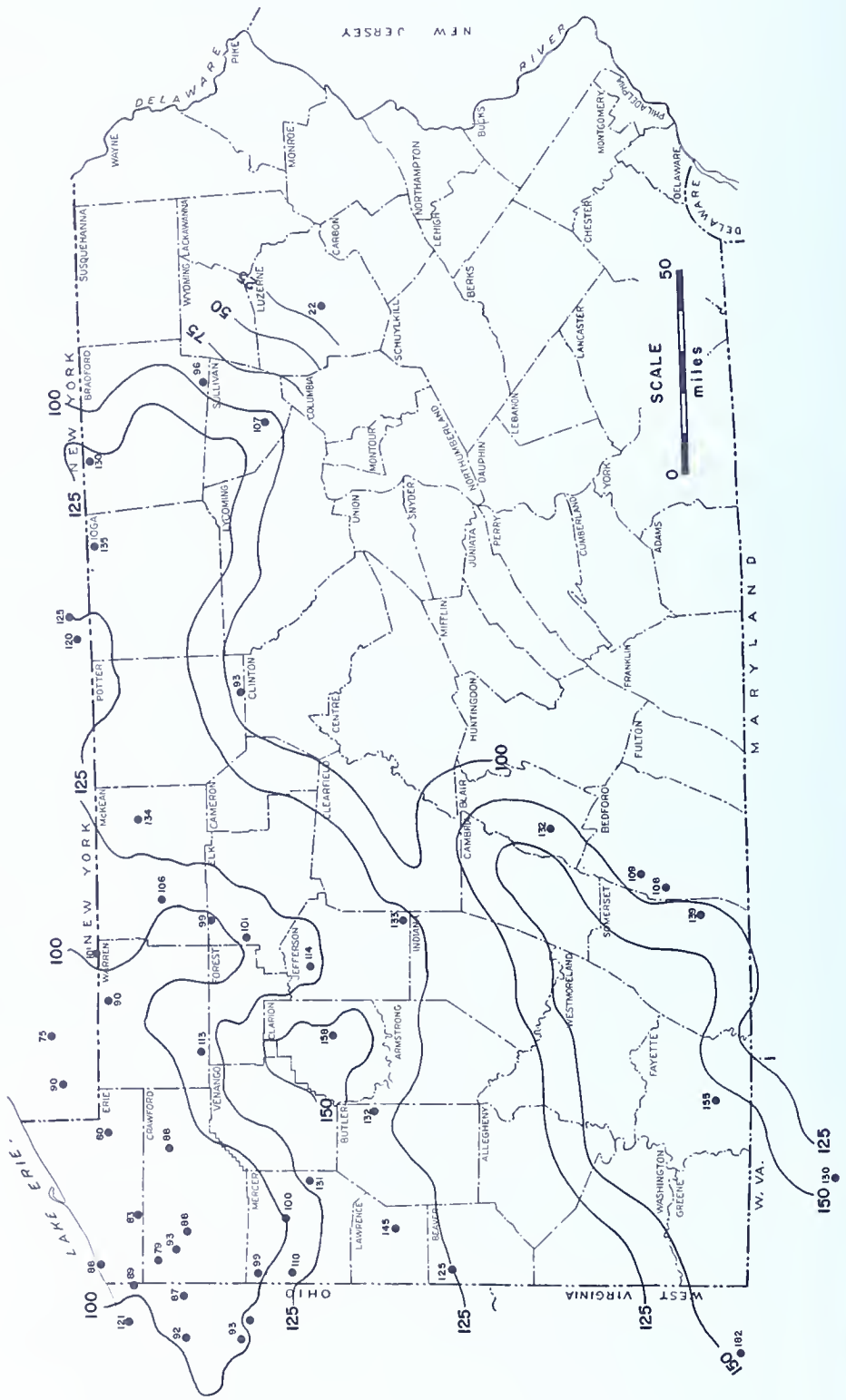

Figure 22. Isopach map of Unit G.

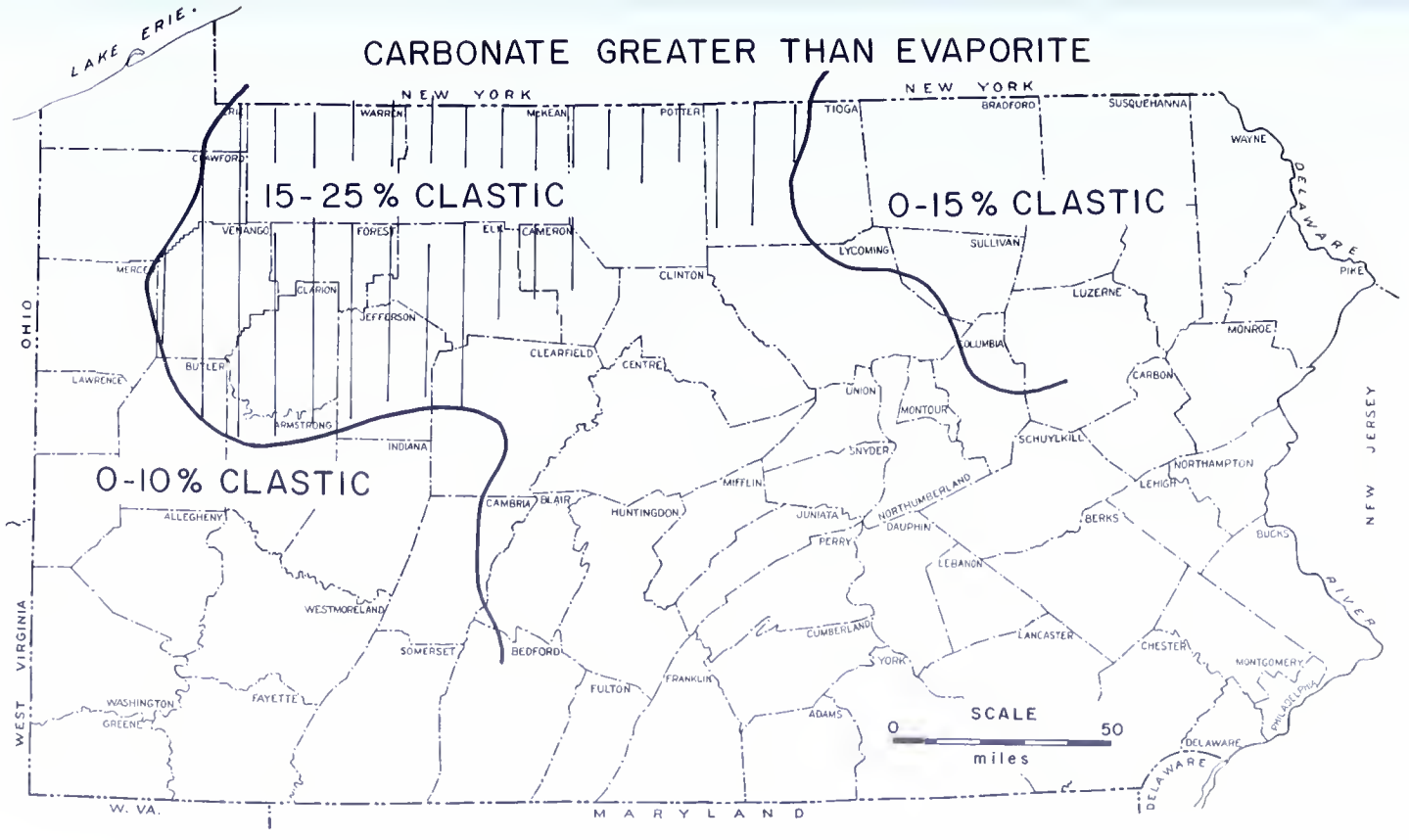

Figure 23. Lithofacies map of Unit G.

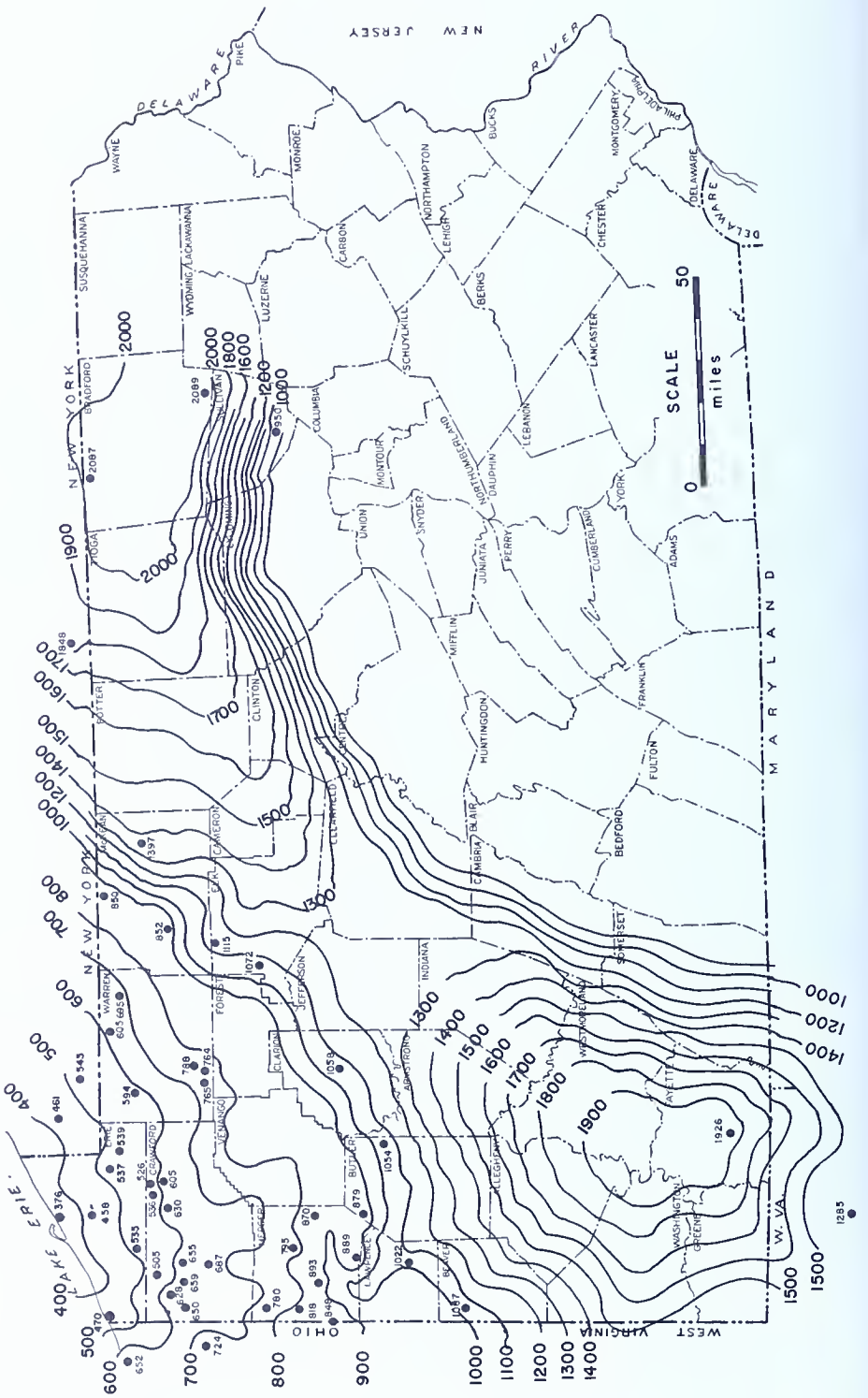

Figure 24. Isopach map of the Salina Group.

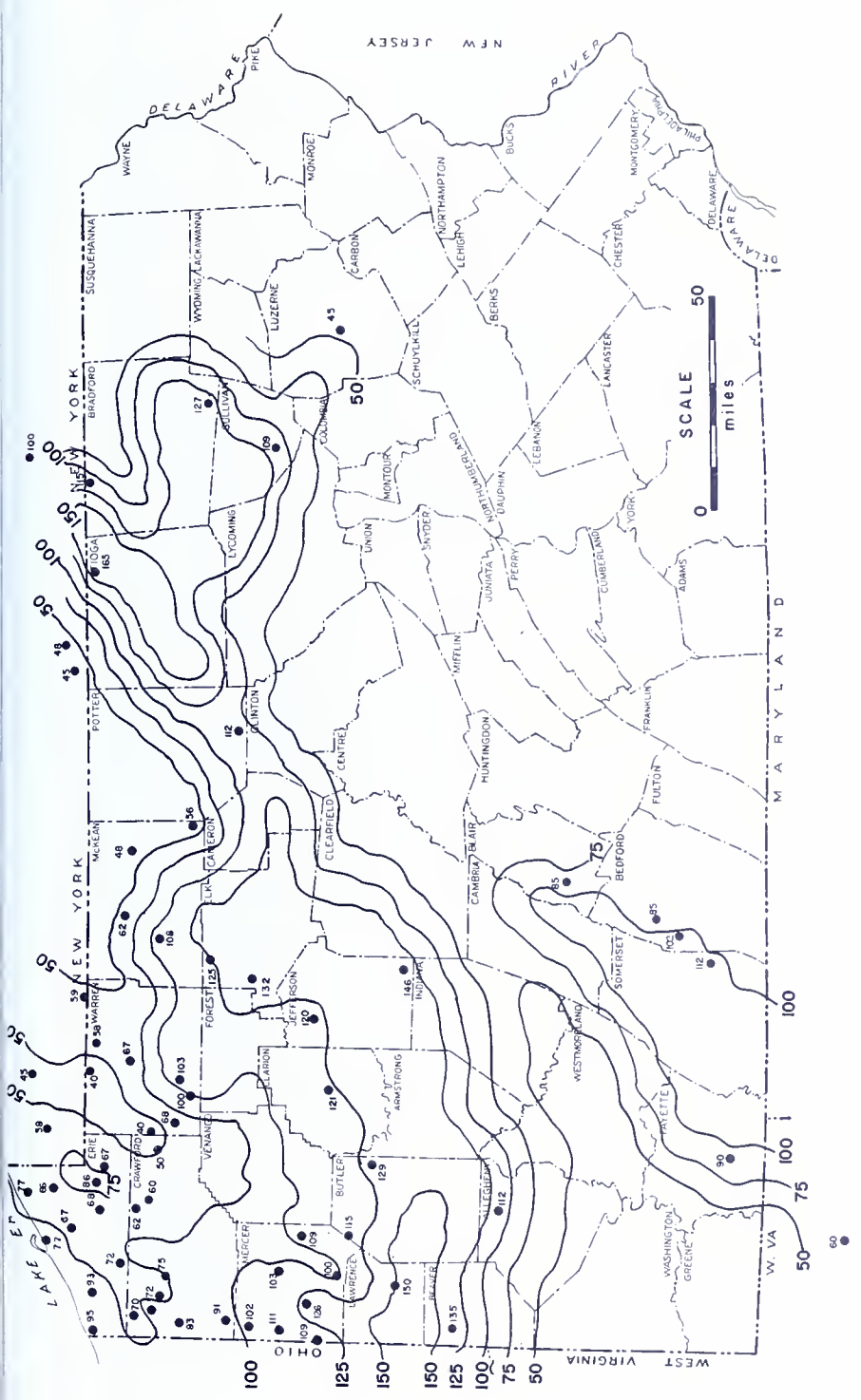

Figure 25. Isopach map of the Bass Islands Group.

ECONOMIC GEOLOGY

SALINA GROUP UNITS

Units B, D, and F of the Salina Group contain thick beds of salt and are potentially of economic importance. The isopach maps (Figs. 6, 11 and 17) and economic maps (Figs. 26 and 27) indicate the location and thickness of the salt beds. The economic maps show areas where a single bed greater than 50 feet is located. Attempts to extract salt from beds below this thickness would probably be uneconomical.

Unit B Salt

The salt beds of Unit B occur in northwestern and north-central Pennsylvania. The salt in the northwestern counties is relatively thin, usually less than 50 feet thick, except in northwestern Erie County where the beds attain a thickness of 80 feet. The unit B salt beds in Erie County are the shallowest salt in Pennsylvania where they lie at a depth of less than 3,000 feet. The unit B salt in Potter and Tioga Counties thickens to about 250 feet. The top of unit B is about 7,900 feet deep in southern Potter County and 10,000 feet deep in Bradford County.

The unit B salt is interbedded with minor amounts of shale, dolomite and anhydrite and is usually contained in two beds. The two salt beds are generally separated by 10 to 15 feet but may be as much as 50 feet apart. The unit B salt is known as the "Number 4" or "Dirty Salt" in Ohio.

The areas in Pennsylvania where the unit B salt is greater than 50 feet thick and contained in a single bed are indicated on Figure 26.

Unit D salt

The unit D salt beds, when present, are usually at the top of the unit and occupy the greatest part of the stratigraphic interval. There are minor amounts of green to gray shale and anhydrite interbedded with the unit D salt.

The salt beds in the northwestern part of the State are thin and are absent in northern Erie County. The thickest sections are located in Lawrence and Mercer Counties. The only possible economic thickness of unit D salt occurs in western Pennsylvania in central Mercer and possibly southwestern Crawford Counties (Fig. 26).

The basin area in north-central Pennsylvania contains thick beds of salt with a maximum single bed thickness of 118 feet in north-central Bradford County. Potter, Tioga, and Bradford Counties all contain thick

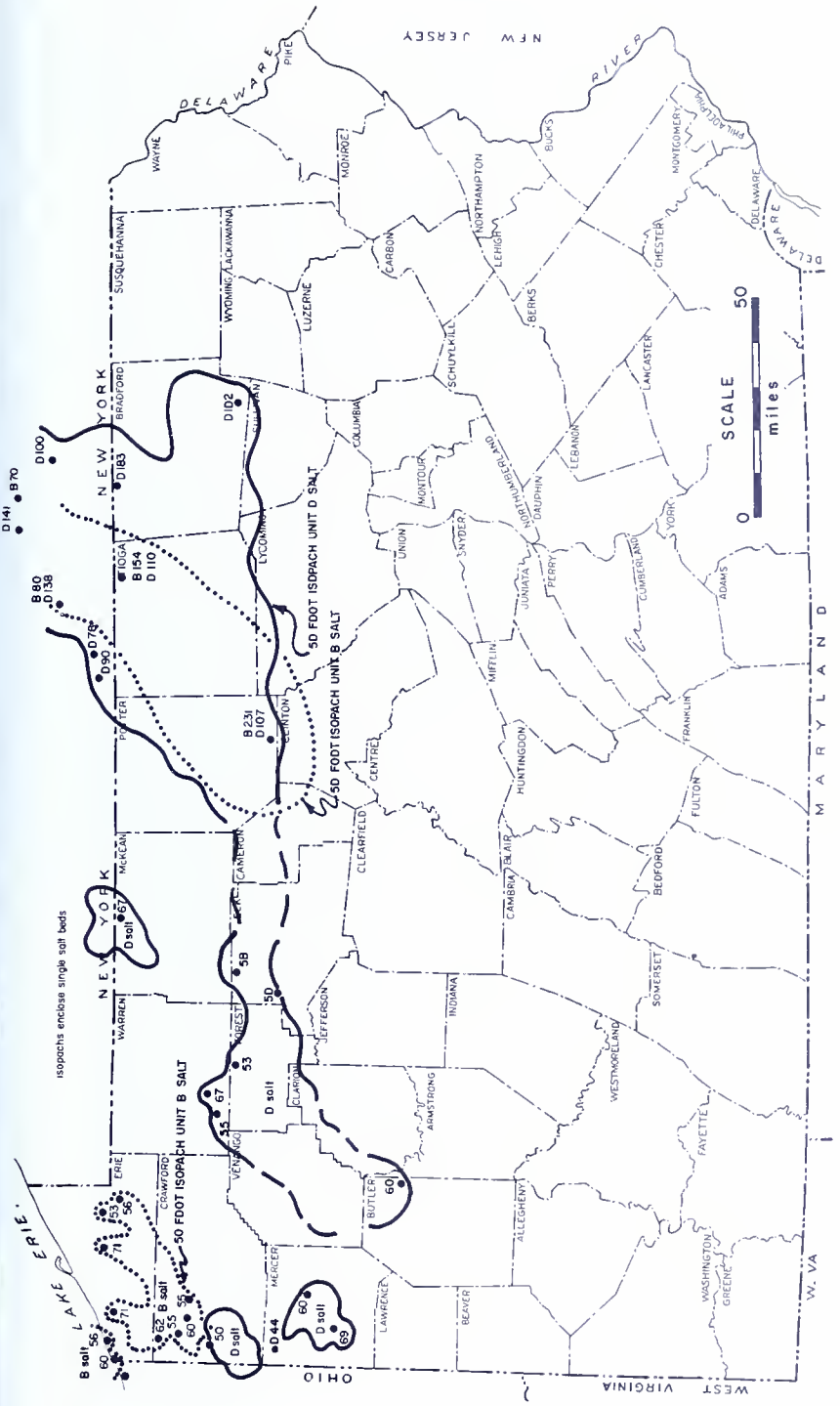

Figure 26. Economic map of Unit B and Unit D salts.

beds of unit D salt and the 50-foot isopach continues to the west to include parts of Cameron, Elk, Warren, Forest, Clarion, Venango and Butler Counties.

The unit D salt is approximately 3,800 feet deep in Crawford County, 4,600 feet in Mercer County, 5,000 feet in Warren County, 6,200 feet in Butler County, 7,700 feet in Potter County, and 9,800 feet in Bradford County.

The unit D salt is known as the "Number 3" in Ohio.

Unit E salt

The thickest occurrence of unit E salt is 37 feet in Elk County. The unit E salt is not considered to have economic potential.

Unit F salt

The unit F salt occurs in three distinct zones and is divided into unit F-1, F-2, and F-3 salt beds. The unit F-1, and F-3 salt beds appear as a thin ribbon extending east from Mercer County that widens and thickens in Potter, Tioga, and Bradford Counties (Figs. 18, 19, 20). The unit F-2 salt has about the same depositional pattern except that a very thick salt section occurs in Fayette County where the F-2 salt attains an aggregate thickness of 542 feet with one single bed containing 450 feet of salt.

The economic map of unit F salt (Fig. 27) shows single beds of greater than 50 feet thickness for all three salt zones throughout the north-central region in Potter, Tioga, and Bradford Counties. The salt in unit F-1 reaches economic thickness in Mercer and parts of Lawrence, Butler, Clarion, Forest, and McKean Counties. Unit F-2 salt appears to be greater than 100 feet thick in Beaver, Washington, and Greene Counties before attaining its greatest thickness of 450 feet in a single bed in central Fayette County.

The unit F salt is the shallowest of the thickest salt beds in areas where the Salina Group has reached its fullest development. The salt beds of the deeper units B and D are shallower in northwestern Pennsylvania than the unit F salts are in the north-central and southwestern regions because of the greater cover of Devonian, Mississippian and Pennsylvanian sediments in those areas.

The approximate depth to the uppermost salt beds may be determined by converting the elevation of the top of the Salina Group (Fig. 28) into depth from the surface elevation and adding the thickness of unit G. Some approximate depths to the uppermost unit F salt beds are: 3,700 feet, Mercer County; 6,100 feet, Butler County; 6,300 feet, Clarion County; 6,800 feet, southern Potter County; 8,900 feet, southeastern Bradford County; and 8,200 feet, central Fayette County.

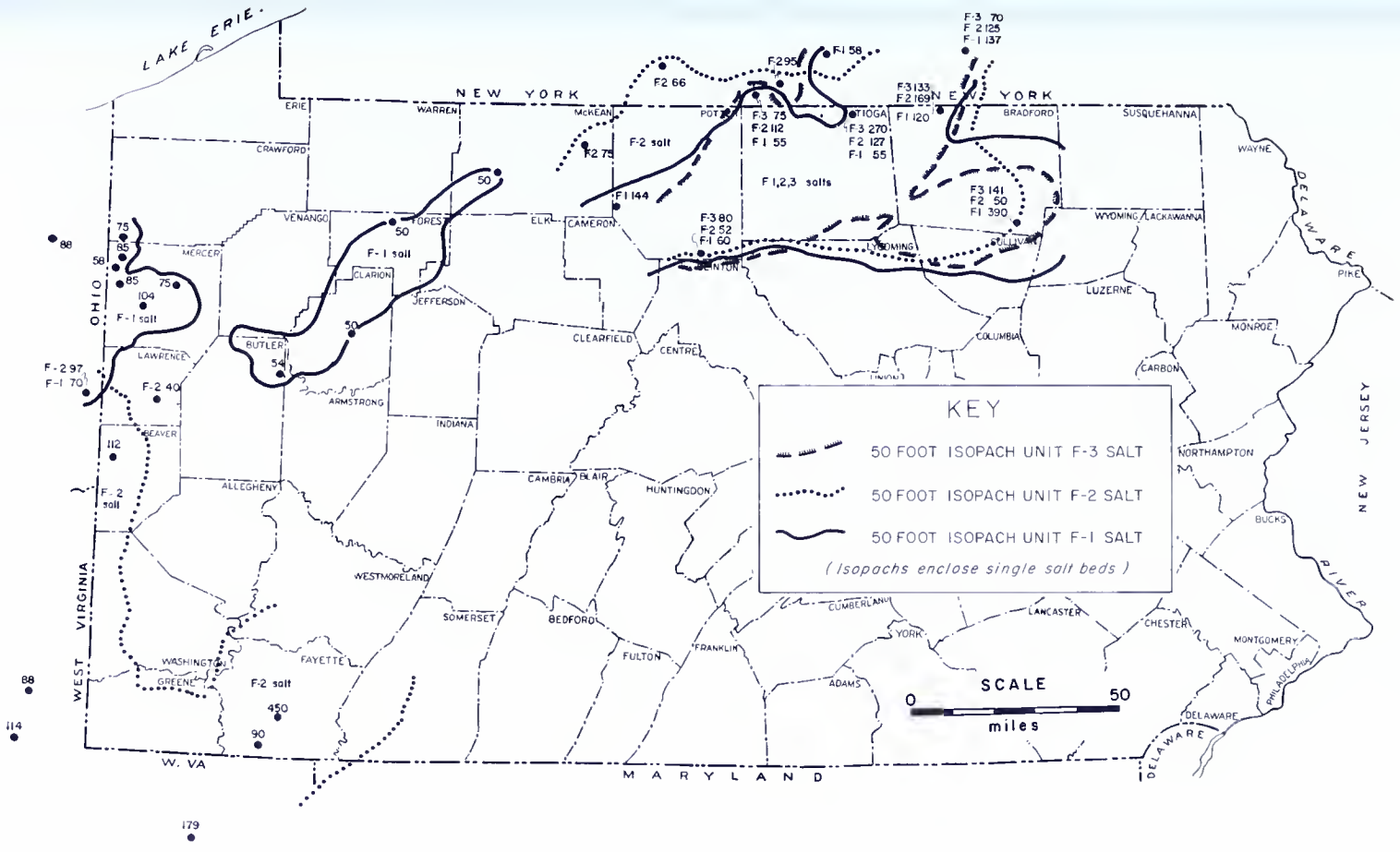

Figure 27. Economic map of Unit F salt.

STRUCTURAL GEOLOGY

Structure contours drawn on the Salina Group (Fig. 28) show a gentle dip of about 50 feet per mile to the southeast from the northwest part of the State to about the −4000 foot structure contour. The −4000 foot structure contour strikes in a northeasterly direction from Beaver to Bradford County. Below the −4000 foot structure contour the dip increases to about 100 feet per mile, and after passing the −6000 foot structure contour, the Salina Group rises at 100 feet per mile to the Allegheny structural front where it or its equivalent appears in outcrop. A broad shallow syncline occurs in Sullivan and Lycoming Counties, and a complementary structural area in the southwestern part of the State contains a broad terracelike area before the beds rise to meet the Allegheny structural front.

The isopach lines of each of the units of the Salina Group, and the thickness axes of the salt beds, parallel the structure contours from northeast to southwest. The lithofacies, as best as can be determined, are in accordance with the basin and platform areas implying that the deposition of sediments expresses a response to the southeast tilting. Subsequent evaporation in the areas of greatest subsidence and environmental restriction resulted in the accumulation of evaporitic sediments.

The axes of the major surface structures in the north-central area (Fig. 29) follow the structure contours drawn on the Salina Group, and parallel the salt-thickness axes. The tectonic axes change to a more southerly direction in the central part of the State where the salt-thickness axes continue to the west. This departure of the salt-thickness axes and the tectonic axes is at the structural lineaments described by Gwinn (1964). The tectonic axes continue through southwestern Pennsylvania through the area in which the thick section of unit F-2 salt was deposited.

The tectonic axes, except one in Clearfield County and two in Clinton County, are located within an area occupied by thick salt beds. The salt-thickness axes zone in the north-central region and the southwestern region may be the result of some tectonic thickening, especially in Fayette County where the thickness axis of unit F-2 salt is located on the crest of the Chestnut Ridge anticline.

The authors subscribe to the hypothesis that the salt was located as a result of the environmental pattern established by the Lockport reefs and the Bloomsburg delta. The salt deposits strayed very little from this pattern because of the slight migration to the southeast by tilting during deposition as shown by the narrow area over which the salt-thickness axes extend. Later tectonism utilized the salt beds as a décollement and the concentric surface folds were localized above the salt deposits with the space requirements for folding being taken up in fracturing and faulting of the competent Devonian beds within the fold cores. The surface structures probably do not continue below the salt beds of the Salina Group (Gwinn, 1964; Prucha, 1967).

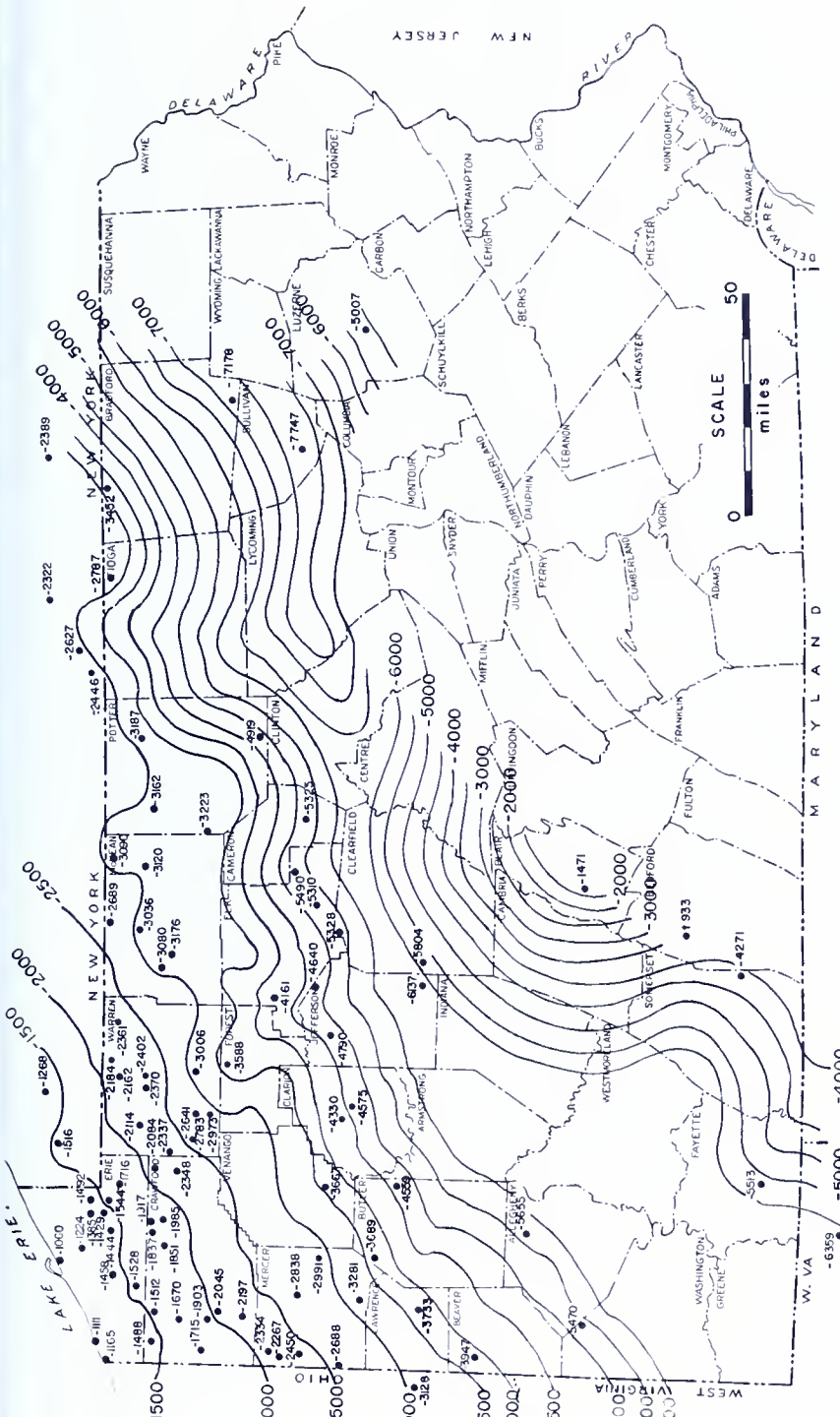

Figure 28. Structure contour map on the top of the Salina Group.

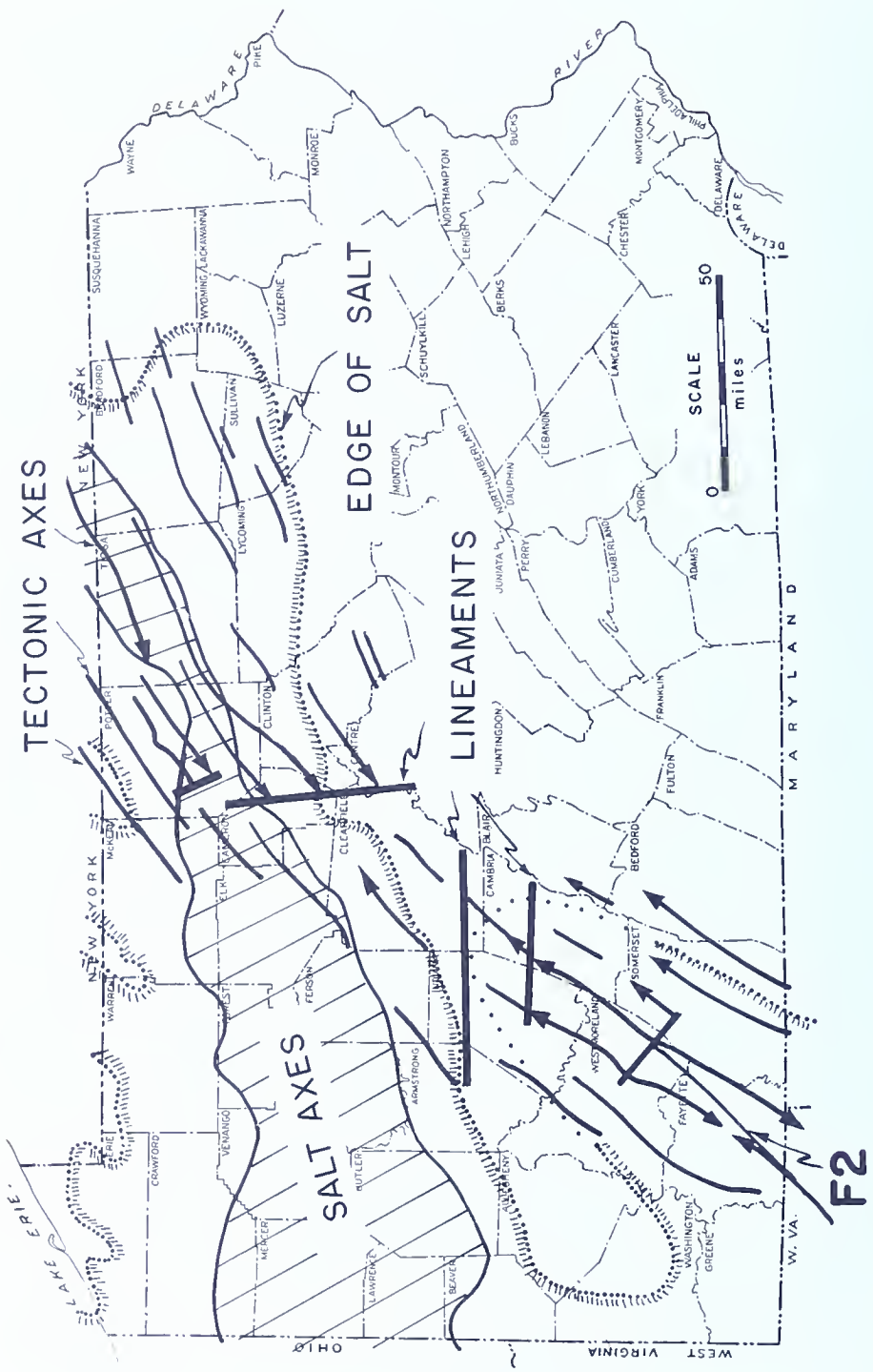

Figure 29. Relationships of salt-thickness axes to tectonic axes.

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